Division of Agricultural Sciences
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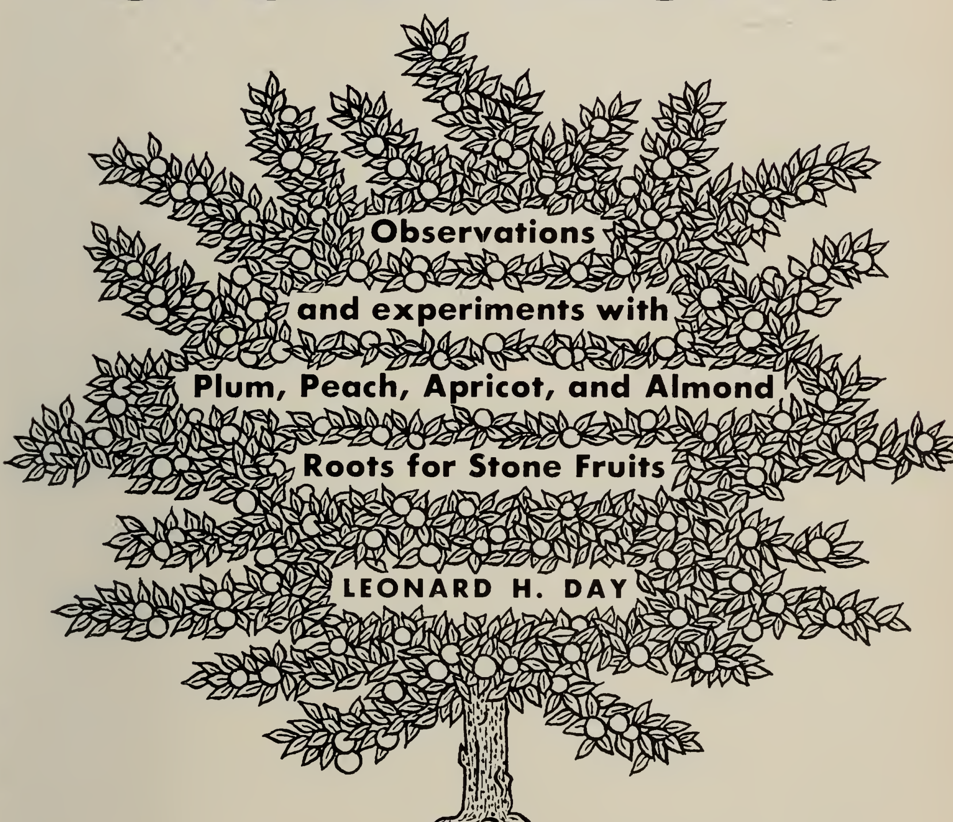
ROOTSTOCKS FOR STONE FRUITS



Observations and experiments with Plum, Peach, Apricot, and Almond Roots for Stone Fruits

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THIS BULLETIN . . .

is a summary of over 30 years of observation and experiments on the behavior of four rootstocks with various stone-fruit varieties. The reactions of plum, peach, apricot, and almond rootstocks to soil conditions and deficiencies are considered, as well as their relative susceptibility to diseases, insects, and animal pests. Ways are described for determining the rootstock species on which the trees are growing in orchards.

Besides the commonly used rootstocks, many other varieties and species were tried, and tests were made of intermediate stocks to overcome incompatibilities of graft unions, or to adapt a variety to some unfavorable soil condition.

It is not the purpose of this bulletin to make recommendations, but from the results reported here growers may be able to recognize some of their own problems and make adjustments that will be of value in their orchards.

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These four rootstocks are considered together in this report because of their mutual grafting affinities—plum, peach, apricot, and almond. Some horticultural varieties of these four stone fruits can be propagated and successfully grown upon seedlings of any one of the four rootstocks. For instance, certain varieties of plums and prunes are grown commercially upon seedling roots of plum, peach, apricot, and almond.

This bulletin reports the fundamental facts regarding these rootstocks, their behavior with various scion varieties and species, and their response to environmental factors—climate, soils, diseases, insects, pests. Cherry rootstocks have been treated previously (Day, 1951). Rootstocks used for apple, quince, and pear were presented by Day (1947).

I. IDENTIFICATION OF THE ROOTSTOCK SPECIES

It is often necessary to determine on what rootstock a nursery or orchard tree has been propagated. In the orchard the four common rootstock species can be distinguished during the growing season by the leaves, provided suckers grow up from below the bud union. The roots of budded nursery trees are readily identified, and nurserymen and inspectors who constantly handle large numbers of bare-rooted trees learn to know them at a glance by color, general form, and a number of more or less indefinable characteristics. The colors and forms vary considerably in different soils and climates. By getting root samples from old trees or by studying the tissues both above and below the union of trees in the orchard, one can quickly learn to distinguish them without removing more than a few inches of soil below the graft union.

Tests may usually be made in a fraction of a minute with the aid of the descriptions below and the photograph shown here (fig. 1). (Heppner [1923], formerly of this station, described certain anatomical differences in the bark and wood of the roots of many trees which may be of assistance to those trained in plant anatomy.) In identifying roots of mature trees make certain that the scion variety has not thrown out roots above the graft union; this often takes place in case the graft union is below ground. Scion roots being nearer to the surface are more likely to send up "suckers" between the orchard rows than are the roots of the original rootstock.

Apricot roots. With nursery stock and young trees, apricot root is easily identified by the beet-red or blood-red[1] color. The surface color of *old* roots of apricot, on the other hand, though dis-

[1] Ridgway's (1912) ox-blood red and Munsell's (1929) Red 3/8.

tinguishable from that of peach and almond is often somewhat similar because in age the latter two tend to become reddish and the apricot to lose some of its brightness. As the trees grow older the inside tissues of the root bark of all four stocks often become red, sometimes clear to the wood, so that deep scraping may confuse rather than aid the identification.

However, in the case of apricot the underside of the surface layer of papery cork tissue approaches violet to red-violet[2] and is of a metallic lustre. This coloration is readily detected by looking beneath sloughing scales or by lightly scraping the surface (especially around the lenticels) to peel back the thin, corky layer. In almond and peach the colors vary from gray to grayish-brown and lack the metallic lustre of that of apricot. With mature trees a thick layer of cork may be present over the surface of the root-crown, and in apricot a dark red[3] color and flecks of violet show on the under surface of, or between, layers of this material. These hues remain on dead roots of apricot a long time unless discolored by decay.

With apricot the corky layer of large roots sheds off but remains adhering along one edge in the form of papery scales, which may attain a width of ¼ to ½ inch. The peach usually has only a few such scales in evidence. The surface of almond and myrobalan root may become rough and covered with minute scales but does not develop such large and conspicuous ones as does apricot (and to a lesser extent peach).

Myrobalan and other plum roots. Young myrobalan plum roots are darker in surface color than those of peach and almond—varying from light to dark chocolate brown.[4] Older roots usually attain a still darker brown color, and when moist they may appear almost black. More rarely, old roots become reddish brown. The outstanding characteristic of large roots of myrobalan, however, is with the lenticels and the numerous long,

[2] Ridgway's Hellebore Red, Deep Hellebore Red, and Mars Violet. Munsell's RP ⅝.

[3] Ridgway's Pompeian Red.

[4] Ridgway's Rood's Brown; Burnt Umber; Chocolate.

Fig. 1. Typical specimens of roots from 15-year-old trees. Notice on the myrobalan the numerous single lenticels between the transverse rows, and the white tissues (left specimen) exposed by scraping off the tops of these structures, also the numerous "wiry" laterals.

fibrous (wire-like) laterals. A greater number of single lenticels are scattered between the cross rows (giving the whole surface a rather "pimply" effect) than is the case with the others—though almond sometimes has some tendency toward this condition in older roots. Moreover, the cellular tissue which makes up the mass of the lenticel is, in case of large myrobalan roots, distinctly white and when the bark is lightly scraped just below ground (for instance, with the shovel) this inner tissue is exposed, giving the scraped area a white-speckled appearance on a dark background.

The above characteristics of the myrobalan seem also common to the other plum stocks such as St. Julien, Marianna, Damson, and the scion roots of European and Japanese plum varieties. No satisfactory way has been found to distinguish these in the orchard from myrobalan, in the absence of foliage or fruit.

Peach and almond roots. Almond and peach roots are much alike in surface color — various shades of light orange or buff[5] when young, though in age they may become pink, red, or dark under various soil conditions. As they grow older peach roots may become brown or, more rarely, reddish brown. The most conspicuous difference between peach and almond is in the color of the inner bark of the root-crown (and up to the graft union)—that of peach having a distinctly yellowish color[6] whereas that of almond is white or pink. One may learn to recognize this yellow color by cutting into the bark of a branch or trunk of any variety of peach or nectarine that has been in the orchard over two or three years, for it is of approximately the same hue as that of the root-crown of peach. The yellow is not present when the tree is planted, but after a year or two a greenish-yellow hue appears, followed by a distinct yellow. It seldom follows far down below the root-crown, and in older trees it may be masked by red except near the wood. In sickly or decadent trees the yellow is sometimes only discovered in small patches at the graft union, and the color quickly disappears entirely when the root dies. No other rootstock of this group possesses this color characteristic, and when this stock is suspected all one need do is to shave down the bark at the graft union or gouge the bark just below the union with a knife.

If for any reason the yellow color has become obscured several other more or less distinctive characteristics will help distinguish almond from peach. Almond bark is definitely thin, being about half as thick as that of peach. The rows of lenticels of peach are usually closer together and are about twice as high as those of almond (also of apricot and myrobalan). Between the rows of lenticels the surface of the peach root is smoother and more glossy than almond. The main roots of peach branch more freely, are less straight, and have more small laterals than those of almond. With peach a considerable number of large, papery scales of cork usually adhere loosely to the bark of old roots, whereas in almond these are characteristically very small, when present at all.

The roots of the so-called Chinese Wild Peach (*Prunus davidiana*) do not have the yellow color in the bark; neither do the oriental species *P. mira* and *P. Kansuensis* nor the California wild peach (*P. andersonii*). The nectarine, however, has the yellow color which indicates its close relationship to the common peach.

II. RESISTANCE TO RODENTS, INSECTS, DISEASES

These four rootstocks exhibit considerable difference in their relative resistances and susceptibilities to rodents, certain common insect pests, and diseases. This is often important in choosing rootstocks for certain situations.

[5] Ridgway's Ochraceous Buff and Apricot Buff.

[6] Approximately, Ridgway's Deep Colonial Buff.

Rodents

Pocket gophers, *Thomomys* sp., often gnaw the bark and may completely girdle the root-crown just below the soil surface. Young trees are most frequently attacked, though the rodents sometimes kill mature trees also in this manner. Apricot and almond are particularly favored by these pests. The peach, though occasionally attacked, is least preferred, and myrobalan stands between peach and the other two. The peach root-crown is not so likely to be completely girdled as the others. Observations in a number of districts show that this rodent seldom bothers apricot trees on peach roots if the graft union is above ground. It was once believed that rodents would not gnaw the bark of almond roots grown from bitter-almond seeds so readily as those from sweet almonds; however, observations by Wood (1947) seem to disprove this idea.

The apricot and almond are more freely attacked by meadow mice than are the others. However, they seldom attack trees except when grass, weeds, or summer covercrops grow close to the trunks.

Insects

Pacific Peach Tree Borer, *Aegeria opalescens H. Edw.:* The peach root borer, as it is commonly called by growers, is confined almost exclusively to the mountain ranges and valleys near the coast of central California. The larvae of this moth burrow just beneath the bark, at or below the soil surface, though sometimes they work a considerable distance up the trunk.

The name would imply that it attacks chiefly peach roots; however, almond, myrobalan, apricot, and more rarely cherry roots are also subject to its ravages. In the nursery it affects peach roots most severely, almond next, myrobalan third, and apricot least. In both the nursery and the orchard the scion variety has some influence on relative susceptibility to this pest.

Susceptibility of the roots in the orchard depends to some extent also upon soil types and the position of the graft union (whether below or above the ground). When the graft is below the soil surface and the union not smooth, the larvae are more able to burrow into the bark at this point. Also, in heavy soil which cracks readily, they get into the bark of the roots more easily than in the lighter soils.

Prune and apricot orchards on myrobalan root are often as seriously infested as are those on almond and peach, and distinctly more so than on apricot root. When the graft unions of apricot trees with myrobalan or peach root are below ground the infestation is more severe than when above ground. Possibly the smoothness (absence of cracks) of the union of apricot on apricot is partly responsible for the lesser infestation in that graft combination, for apricot on apricot root can become seriously affected once this pest is permitted to get a firm foothold in the orchard. The smoothness of the union makes inspection and removal of the borers less difficult on apricot root. In the case of apricot on myrobalan the borers often follow a rough graft union (especially if below ground) directly around the trees, whereas with apricot root they are more likely to proceed directly downward to the root-crown. With apricot trees on apricot root, in mountain districts where the Flickers, *Colaptes cafer collaris*, are plentiful, these birds will often keep the pest in sufficient control; but with myrobalan, peach, and almond roots additional means of control are often necessary.

Myrobalan seedlings planted in the orchard are not so freely attacked as are French prune trees on myrobalan root worked at the ground. In case of the latter, the borers are worse if the graft union is even slightly below ground than when above. Also myrobalan seedling replants, grafted high (in the main

branches) in the orchard to French prunes, are not so freely attacked as those worked on myrobalan trunks. Roots of prune trees on almond root are about as freely attacked as are those on peach root.

Red Spiders and Mites. In the nursery almond and myrobalan seedlings frequently require treatment for spider mites; peach and apricot are least subject to these pests. Occasionally peach has had to be treated.

In some seasons in the San Joaquin and Sacramento Valleys, French prune on peach root is not so severely attacked by spider mites (probably *Tetranychus pacificus* McG.) as it is on myrobalan root. However, this difference is not great enough to matter in choosing rootstocks — there being more important reasons for rootstock preferences.

Nematodes

Root-Knot Nematode. (*Meloidogyne* sp.):[7] In this group of rootstocks, apricot is the only species uniformly resistant to the root-knot nematode. Some varieties or hybrids of the others are, however, more or less resistant. For instance, certain selections of myrobalan are resistant when propagated by cuttings; the Marianna plum and its seedling selections are highly resistant; seedlings grown from seeds of certain varieties of peaches (See page 49) are partially resistant; and a few individual almond seedlings have been found which possess considerable resistance.

In a nematode test nursery at Delhi, California, the seedlings of 45 varieties of the common apricot were tested, and all were highly resistant. Occasionally a tree in the orchard is affected, but seldom has this been found particularly severe. In one case of peach on apricot root, inspection revealed that some of the peaches had grown scion roots above the apricot, and it was these scion peach roots that were affected by nematodes. In these cases the weakened roots had become reddish; hence the error in considering them to be infested apricot roots. Also the seedlings of two other apricot species—*P. mume* and *P. dasycarpa*—have been found practically resistant.

Almond seedlings will usually tolerate a greater concentration of this nematode in the soil than will ordinary peach seedlings. Quite commonly growers have, by liberal irrigation and nitrate fertilization, been able to grow almond trees on almond root in nematode-infested soil. Apparently deeper penetration and wider ranging of almond roots, as compared to peach, makes this possible where nematodes are not abundant. In such infested soils, however, there are usually small areas where nematode attack is too severe, and recourse has had to be made to nematode-resistant peach roots for almonds in these small areas. In the nematode test nursery a few individual seedlings from several almond varieties and almond seedlings of known parentage have been found which seemed to have considerable resistance to nematodes. Some of these have been planted at Davis for seed production, with the hope of finding one or more whose seedlings would be sufficiently resistant or tolerant to this pest.

The following vegetatively produced plum roots were found by Tufts and Day (1934) to be resistant to the rootknot nematode: the very vigorous Myrobalan 29[8] (grown by cuttings), California Station myrobalans No. 2–7 and 8–10 (both grown by cuttings), St. Julien E, St.

[7] Nematologists have recently determined that more than one species of root-knot nematode affect the roots of fruit trees in California, all belonging to the genus *Meloidogyne*. (This replaces the former name *Heterodera marioni.*) It is impossible to state at present which species of *Meloidogyne* were involved in all the cases reported by Day and Tufts (1944).

[8] Note—Since these tests were made it has been found that Myrobalan 29 consists of a mixture of several strains of vigorous myrobalans, and it is not certain that all the strains were included in the test material.

Julien G, Black Damas C, Marianna, and several selected seedlings of Marianna (particularly California Station No. 2616, 2623, and 2624). Seedlings of improved Wild Goose (*P. Munsoniana*) and *P. hortulana* were also found to be resistant. Many other strains of myrobalan were tested, and all proved to be quite susceptible. In the paper cited above, myrobalan B from the East Malling Station was reported resistant. However, it has since been established that the strain we used was not the true East Malling myrobalan B, but instead is the variety Marianna sent us by error.

Lesion or Meadow Nematode. (*Pratylenchus vulnus*)[9] This nematode, which causes bark cankers rather than beadlike knots on the roots, attacks all the rootstock species discussed here. Besides causing cankers on large roots it often kills many of the small feeder roots. How severe the damage is to trees on all of these stocks is not known, though perhaps it is most severe on peach-rooted trees. Serr and Day (1949) and Day and Serr (1951) reported results of a five-year test plot on a soil having a high population of this nematode, in which were all the rootstock species included in this bulletin, besides many other species of stone fruits which might be usable if they should prove resistant or immune. The above tests indicate that the peach and plum varieties resistant to the root-knot nematode are not resistant to this species. However, one myrobalan selection (grown by stem cuttings) and Blenheim apricot seedlings have considerable promise. These tests must be continued for a longer time to make certain of their resistance.

Diseases

Oak-Root Fungus Disease, *Armillaria mellea.* The roots of all the stone fruits are subject to infection by the oak-root-fungus root rot. Trees on peach, apricot, and almond roots are more susceptible than those on myrobalan and Marianna. Thomas (1934) and others have found that the fungus extends more rapidly through dead than through live roots. This perhaps explains the rapid increase in spread sometimes observed where a circle or two of unaffected trees have been pulled out around an oak-root-fungus area. In orchards affected by this disease replants on myrobalan and Marianna roots do not usually begin to die before the third or fourth year; many survive 10 to 15 years. Apparently they are not so readily attacked while in vigorous growth condition.

In affected orchards a few myrobalan-rooted trees have withstood the disease for over 20 to 25 years. In the hope that these may be practically resistant, a number have been selected, propagated by cuttings, and planted in oak-root-fungus affected spots in orchards. Observations and preliminary tests indicate the existence of certain strains of myrobalan more resistant than others.

The parent Marianna plum root was not used in former years by a sufficient number of orchardists to afford much evidence on the behavior of this rootstock in regard to oak-root fungus. The few cases found and some tests in recent years indicate that, though not immune, it is more resistant than the general run of myrobalan seedlings. Tests of several vigorous seedling selections of Marianna indicate that one (University of California Selection 2624), grown by cuttings, has some promise of sufficient resistance to be of practical value. Many years of trial will be required to determine whether the parent Marianna or its vigorous seedling Selection 2624 will be resistant enough to be of material benefit in preventing spread in affected spots within orchards. Approximately 10 per cent of the test trees of Marianna 2624

[9] Studies by Allen and Jensen (1951) of the University of California (Division of Entomology and Parasitology) indicate that nematologists have hitherto mistakenly identified the species with which we were working as *P. pratensis.*

(nine trial plots in five counties) were killed during the first 13 years.

Since no evidence of resistance has been observed among seedlings of peach, almond, and apricot, it appears likely that commercial varieties may have to be grown on plum roots—if a sufficiently resistant one is found. Almond and peach varieties may be successfully grown on certain plum roots directly or by the use of some intermediate stock. Apricots grow fairly well on myrobalan and Marianna and perhaps would do well on any oak-fungus-resistant plum stock discovered. Since peach and almond are not quite so compatible with plums, it may be that the plum roots would be more susceptible to the disease when top-worked to them. Certain almond varieties do fairly well on Marianna Selection 2624, but resistance of this root to the disease might be much decreased when top-worked to them. Etters Best, a hybrid between the Sierra wild plum (*P. subcordata*) and the Domestica plum of Europe, seems to have considerable resistance, suggesting that by hybridization a satisfactory stock with hybrid vigor might be developed. Blenheim apricot and several plum varieties have grown well upon Etters Best. The oak-root-fungus disease has never been observed to attack the Sierra wild plum. Several natural hybrids have been found in the mountains near old residences where domestic plum trees once grew. These are being grown by cuttings to test their suitability as rootstock material.

Trees on promising rootstocks must be planted with the graft unions several inches above the soil surface, for the disease may attack them above the union if they are planted so that the scion variety is below ground.

Planting ungrafted rootstocks for the purpose of later top-working to the desired variety has some risks because the temporary shock from heavy topping at grafting time may enable the fungus to get established in the roots. This has been observed occasionally in top-working stocks even as resistant as Northern California Black walnut.

Including the above strains, we have approximately 100 plum varieties and species under test as rootstocks in areas affected by oak-root fungus. Some growers have been replanting diseased areas with common myrobalan root rather than mixing into their orchards such inharmonious resistant roots as Northern California Black walnut, fig, and French pear. They realize, however, that because of the oak-root fungus many of the myrobalan-rooted trees will never reach maturity.

Crown Gall, *Agrobacterium tumefaciens.* The bacterial organism causing crown gall is apparently present in native plants in many soils of the Pacific Coast, for it attacks the crowns and roots of trees wherever nurseries are planted. Though it seems to vary either in concentration or virulence from place to place, yet in selecting a nursery site no practical method has been found to determine these facts.

Of this group of stone fruits almond roots are the most susceptible to crown gall, followed in order of increasing resistance by peach, myrobalan, and apricot. The wild Chinese peach (*Prunus Davidiana*) is more susceptible than any of them, and the Marianna plum least. French prune propagated on its own roots from rooted suckers seems quite free from this disease. This is also true in general of the European plum varieties (*Prunus domestica*) grown on their own roots by layers or other means. Marianna and its vigorous seedling Selections 2624 and 2623 seem more resistant in the orchard than myrobalan seedlings, though in the nursery the basal ends of the cuttings may become infected.

Large crown galls with dead centers often give entrance into large roots to wood-rotting fungi. For instance, an old apricot orchard on peach and apricot roots, pulled up at the Wolfskill Experi-

mental Orchard at Winters, revealed much rotting of peach roots originating in crown galls, whereas apricot roots were comparatively free from rotting even though they had large crown galls. Old almond trees on almond root and Beauty and Grand Duke plums on myrobalan root were comparatively free from wood rots originating in this way, even where many old galls were present. However, peaches on almond root have frequently been observed to split apart because of heart rot originating in old crown galls on the roots.

Crown gall and the wood rots which get a foothold in the dead tissue caused by this disease were found, in one orchard of very large French prune trees on peach root, to be the cause of the early decline of the trees. Those on myrobalan root in the same orchard were not so seriously infected with wood rots, even when crown galls were present. Often large branches of trees weakened by wood rots (originating in crown galls) are readily split off by wind storms.

Confirming the experience in the nurseries at the Davis Station, a number of nurserymen report that seedlings grown in beds and transplanted to the nursery are more subject to infection than are seedlings grown by planting seeds directly in the nursery row. They report also that if stratified seeds begin to grow before planted they are more subject to infection—the organism apparently getting into wounds made during planting operations. Nurserymen have found that cuttings of various kinds are particularly susceptible at the basal cut, the infection possibly entering wounds in the callus tissue or wounds made while planting or by insect larvae in the soil.

Blackheart, Verticilliosis, *Verticillium albo-atrum* Reinke and Berth. Both in the nursery and in the orchard this disease occasionally affects trees on myrobalan root, but apparently not so commonly, or at least so injuriously, as it does trees on apricot. In one nursery it was observed to be more serious with apricot on apricot roots than on apricot on myrobalan, though it was particularly frequent on late Satsuma plum on myrobalan. Such differences might be due to the local distribution of the disease in different soils. One nurseryman stated that in his nursery apricot on peach root was more commonly affected than apricot on myrobalan, and several reported it on peach and almond, though more frequently on apricot and myrobalan roots. Rudolph (1931) reported that myrobalan seedlings were very susceptible to blackheart.

Bacterial Gummosis, Bacterial Canker, *Pseudomonas Syringae* (Van Hall) Bergey *et al.* The rootstock on which plum, prune, and apricot varieties are growing sometimes has considerable influence on the susceptibility of the tree to bacterial gummosis. Trees on peach root are less susceptible than those on myrobalan and Marianna roots. Apricot varieties on apricot root likewise are more susceptible than they are when on peach root, but less so than on myrobalan.

In Placer County it has been observed by the author (Day, 1947) during many epidemics over a period of 20 years that Santa Rosa and Duarte plums on peach root which have grown scion roots above the graft union are much more susceptible than those which have not grown plum roots. By cutting off the scion roots several orchardists have apparently greatly reduced the severity of the disease.

In 1935 in a severely affected young Santa Rosa plum orchard near Penryn, we replaced dead trees with 36 Santa Rosa trees which had been propagated on their own roots by cuttings and by layering. The owners had been replanting for several years with Santa Rosa on peach root. In 1937 bacterial gummosis killed a few of the own-rooted trees, and in the spring of 1938 all were killed, whereas only a few of those on peach root were injured.

In a number of Placer County orchards plums top-worked upon the branches of peach varieties were more free of the disease than those grafted at the ground upon peach-seedling roots. Bacterial gummosis (sour-sap type) has attacked young trees of President top-worked upon peach, the disease running downward in the peach branch to the trunk in cases where the grafting was quite low, whereas in cases of high grafting many of the cankers did not progress down to the trunks.

Salwey and several other varieties of peaches have considerable resistance to bacterial gummosis. About 20 years ago this variety was planted on peach root in a few plum orchards and top-worked to the desired plum variety when two to three years of age. The disease has not been so severe in these trees as in trees on plum root. Its most destructive effects come from infections which girdle the trunk or the lower parts of the scaffold branches; therefore a resistant understock of peach should be of value.

President, Duarte, Clyman, Wickson, and Santa Rosa plums especially require some such procedure in Placer County to reduce the ravages of this disease. French prune is not very susceptible, but occasionally it is severely attacked. In every instance where soil and other conditions were sufficiently uniform to make comparable observations, it was seen to be less severe on peach than on myrobalan root.

Observations in Santa Benito County and throughout the interior valleys—particularly in Kings, Merced, and Stanislaus counties (Day, 1947)—indicate that apricot varieties on myrobalan are much more subject to bacterial gummosis in these districts than they are on apricot and peach roots. Also, those on peach root are less subject to the disease than are those on apricot root. The disease in these cases was mostly of the sour-sap type which kills the trees without much evidence of gumming (see also pages 30 and 31 for further discussion on this subject).

Young trees up to 10–12 years of age are more subject to this trouble than are older trees. Cankers do not progress downward more than an inch or two below ground, and the infections seldom begin below the soil surface. In the case of susceptible rootstocks, and with the graft unions above ground, the infections occasionally begin at or below the graft union. When trees are killed, sprouts sometimes grow from the rootstock. In case the disease is confined to the upper parts of the trunks of young trees, sprouts from the scion variety will sometimes grow above the union. In one case about 75 young Blenheim apricot trees were girdled in the upper parts of the trunks in early spring, and the tops were dying at the time of discovery. The trunks were immediately sawed off a few inches above the graft unions; new Blenheim sprouts grew and the trees were saved.

Seedlings are sometimes planted in orchards for later top-working to the desired varieties. In areas where bacterial gummosis is common there is considerable risk of infection either before or after top-working. Apricot seedlings are very susceptible. The myrobalan varies in susceptibility from seedling to seedling. Myrobalan 29 is fairly susceptible, as is also Marianna Selection 2624. The parent Marianna seems fairly resistant. No observations have been made in this regard with the other Marianna selections.

Crown Rot or Phytophthora Cankers. Bark cankers caused by infection by water molds (especially species of *Phytophthora*) at or near the soil line, or on the root crown, often girdle and kill trees following floods or protracted wet soil or surface conditions. Infection probably occurs mostly during the late winter and early spring, and often short periods of exposure to wet conditions can result in infection. Apparently warm weather at the time of exposure is par-

ticularly conducive to infection. Myrobalan root is much more resistant to the disease than are apricot, peach, and almond; but since myrobalan is more generally used than other stocks for heavy or wet soils, this trouble is occasionally observed with trees on myrobalan roots. Apricot root is slightly more resistant to the crown-rot fungi than peach; and almond is the least resistant.

In epidemic form the disease occurs only periodically; in some years there are few cases. Smith (1915) reported it to be particularly common in 1914 and 1915 on nursery stock of peach and almond varieties on these two roots. In San Benito County the author observed it in orchards from about 1914 to 1921 to be more common on French prune on peach root than with apricot on apricot root. Smith and Smith (1925) reported its occurrence in epidemic form in other parts of the state in 1921 and 1922. In these years they reported that it killed many trees in orchards of peach, almond, plum, prune, apricot, pear, and black walnut. They did not make a record of the rootstocks on which the stone fruits were growing, though undoubtedly the peach was on peach, and almond mostly on almond. Hunt (1921) also reported on the 1921 epidemic. The disease was again common in later years, particularly 1927, 1928, 1938, and 1941. Nearly every year trees in small isolated areas are affected.

The bark cankers usually occur at or immediately below the soil surface, though they may occur above ground (especially on young trees) or at some distance down upon the main roots. In years favorable to the growth of the crown-rot fungi, not only are trees killed in particularly wet areas, but scattered cases occur even in well-drained areas—especially in young orchards. Often the affected trees have been observed to have dried grass, weeds, or leaves piled up around the crowns. Sometimes high covercrops close to the trunks seem to have furnished proper conditions in wet seasons for fungus infection, particularly to peach and almond.

Cankers occurring on the trunks above ground resemble somewhat those of bacterial gummosis, but cankers of the latter seldom extend over an inch or two below the soil surface. Also in case of bacterial gummosis, sprouts often grow up from the crown (especially with myrobalan-rooted trees); this is quite rare with crown rot.

Growers and nurserymen sometimes call crown rot the "heeling-in disease" because it frequently affects nursery trees after they are dug and temporarily "heeled in," particularly in wet soil or if held there during protracted rains. Trees held in sand or such materials as sawdust and shavings are less commonly affected. The organisms often gain entrance through bark that has been bruised or cut during digging and handling operations in the nursery or during orchard planting. Growers are prone to blame the nursery for the disease in newly planted trees, whereas undoubtedly the trees often become infected by these organisms in the soil where the grower heeled them in, or from the orchard soil in which they are planted.

Observations in the wet seasons of 1938 and 1941 indicated that crown rot was particularly common with peach root where late fall irrigations applied for cover-crops had kept the soil wet over a long period of warm weather. In one district of deep sandy soil, early heavy rains one year caused crown rot in peaches on peach root that was detectable by the first of December.

It is likely that many cases of tree death reported to be due merely to too deep planting are really a matter of infection by crown-rot fungi rather than a "sour sap" or physiological difficulty. Many growers have stated that, in heavy soil, planting trees even on myrobalan root, with the graft unions below the ground level, will often result in the death of the trees. It is likely that this physio-

logical explanation has been too freely used to explain the dying of deeply planted trees.

Further discussion of this disease occurs in the section dealing with tolerance of the four rootstocks to wet soils (p. 18).

Sour Sap. See discussions under the section entitled, Tolerance of the rootstock species to wet soils (p. 18) and under Bacterial gummosis (p. 11), Crown Rot (p. 12), and Blackheart (p. 11). All these diseases are often referred to by growers as "sour sap."

III. DEPTH OF PENETRATION OF ROOTS

In this connection reference is usually made by horticulturists to the main roots and less consideration given to the laterals and finer feeding roots. These latter greatly extend the root system both horizontally and in depth, and consequently strengthen the anchorage or roothold to the soil and increase feeding range. The fact that the main roots of a tree start directly downward may not necessarily prove that its feeding roots penetrate to greater depths than do those whose main roots spread out more horizontally.

Nor does a horizontal, spreading root system necessarily indicate a spread to greater distances away from the tree trunk. For example, almond roots usually penetrate directly downward more freely than those of the other stone fruits of this group, and at the same time small roots of almond appear to spread out into surrounding surface soils as efficiently as those of the other stone fruits in gathering moisture, perhaps to an even greater distance. Experienced growers have expressed the opinion that almond roots penetrate more deeply than those of other stone fruits, and that this deep-penetrating characteristic enables trees on this root to withstand dry-soil conditions longer than on other roots. Though trees on almond root seem to have greater drought resistance, it is not entirely certain that this is due solely to greater depth of root penetration and horizontal root spread.

Apparently because of the downward strike of almond roots, trees on this stock are the most difficult of any to pull with a tractor. The tree shown below, left (fig. 2) could not be pulled with a 90-horsepower tractor until some of the

Left, fig. 2. Root system of an almond tree 16 years old. This tree pulled with such difficulty that it was necessary to cut off 5 large surface roots (A, B, C, D, E) before it could be uprooted with a 90-h.p. tractor. At a depth of 7 feet several main roots were approximately 2 inches in diameter. Not all almond root systems have as many main roots descending vertically as did this one. Right, fig. 3. Apricot seedling roots. Note that many of the main roots descend at a steeper grade than do those of myrobalan and peach roots but not so vertically as almond roots.

 

Left, fig. 4. Peach seedling roots, 15 years old when pulled. This illustrates the horizontal rooting habit of the main roots of peach seedlings. Right, fig. 5. Myrobalan roots, 15 years old, showing horizontal growth habit of main roots.

larger side roots were severed with an axe. In the same soil trees much older and larger, on other roots, were more readily pulled by the same tractor.

Next most difficult in this respect are trees on apricot roots (fig. 3). Observation indicates that the main roots, though not striking downward at so steep a grade as those of almond, are not usually so horizontally rooted as those on peach and myrobalan. However, in several unirrigated districts, growers report that apricot trees on apricot root do not do so well as those on peach root. Contradictory evidence exists as to the relative drought resistance of apricot trees on the two stocks, and there has been no opportunity to study the various complicating factors. Illustrations at page top (figs. 4 and 5) show the more horizontal rooting habit of peach and myrobalan roots.

There is much variation in form and angle of the downward penetration of main roots of any one of these four stone fruit species. Individual almond seedlings may occasionally be as horizontally rooted as peach roots, and vice versa (peach seedlings sometimes having "tap" roots growing downward). Bokhara peach seedlings quite commonly have main roots which grow directly downward.

Relative tolerance to drought of trees on the four rootstock species is particularly noticeable in the case of French prune, which sometimes drops a large proportion of its leaves when the readily availably soil moisture is near exhaustion. This has been observed a number of times in the coastal areas. Also in this region unirrigated or lightly irrigated prune orchards occasionally drop a considerable amount of fruit following an unusual hot spell, when the available moisture supply is limited. Observations such as the above indicate that, in order of decreasing resistance of French prune to drought, trees on almond are the most tolerant, followed by myrobalan, peach, and apricot.

Apricot trees retain their leaves better than French prune under dry conditions, but apparently their success depends on the rootstock in the same order as given above for French prune (excluding almond root, of course, because apricot is not compatible with almond root).

The main roots of the myrobalan are not normally large in diameter nor particularly deep-penetrating (tending like the peach to spread out horizontally). However, judging from the fact that French prune on myrobalan root withstands drought conditions better than it does on peach, it is likely that the smaller roots penetrate to greater depths than do those on peach.

In a 13-year-old orchard of peach on peach root and prune on myrobalan roots, growing on a deep, uniform Yolo soil at Davis, Veihmeyer and Hendrickson (1938) by systematic sampling found that there was such uniform extraction of soil moisture at comparable depths as to indicate that these two rootstocks had, in this particular soil at least, a uniform distribution of feeder roots throughout the soil mass at any specified depth level (at least to the depth sampled—6 feet). No difference was found in the rapidity of extraction of soil moisture near the trunk and out to the middle of the orchard rows. However, the rate of extraction was slower with depth—indicating a less concentrated population of roots at greater depths.

The root system is forced to larger size and spread by vigorous scion varieties. With prune and plum tops, the myrobalan and peach root systems are very much more slender and restricted in range than when the top variety is the more vigorous apricot. This is very evident both in the nursery row and in the orchard. The relative depth of the main roots of the rootstock species is pretty well indicated by their behavior in strong windstorms. This was studied following several such storms, in which many thousands of trees were blown over. Anchorage to the soil may depend in part upon the number and branching of smaller roots. Notwithstanding their much larger tops, apricot on myrobalan root were less disturbed by strong winds than French prune on myrobalan. French prune on almond root were seldom uprooted, and almond on almond root proved much better anchored than almond on peach. French prune on peach roots resisted wind pressure a little better than did those on myrobalan but not so well as those on apricot.

The mechanical or physical composition of the soil seems to be a large factor in depth of penetration and distribution of the root system, and apparently the various rootstock species are influenced in different degrees by the soil type. Compact soils perhaps retard root penetration physically, and also by their high water and low oxygen content at critical growing periods.

In a 25-year-old French prune orchard on myrobalan root in Sacramento County, with unusually large tops on deep, fertile, well-drained soil, which was not irrigated until the trees were 20 years old, the main roots at least were surprisingly shallow. About 3,000 of these trees blew down in a strong windstorm following heavy rains which had softened the soil.

In several apricot orchards in shallow soil with loamy surface soil and compact clay at 16 to 20 inches, myrobalan roots did not penetrate the clay so freely as did apricot roots. The terminal portions of the myrobalan roots subdivided into fine rootlets which spread out, fanlike, upon the clay. Trees on this root were more readily pulled by tractor than those on apricot. In a number of instances of prune orchards on myrobalan on soils similar to the above, many trees blew down in heavy wind storms following prolonged rains, apparently because they had not developed strong anchorage roots into the clay subsoil.

Variation in soil nutrients and moisture content in the various soil layers

may also have a large influence on root penetration. A number of instances have been observed where the roots of deciduous fruit trees do not penetrate so readily into soil horizons containing high percentages of sand as in soils containing larger quantities of silt or clay material. In one Sacramento County orchard in sandy, deep soil some peach trees were pulled by tractor, and the roots were found very near the surface—evidently doing all their feeding in the silty surface horizons. Beneath the flat root system for several feet in depth there was almost pure sand.

In a young peach orchard on peach root pulled by tractor at Delhi, in very sandy soil, a great variation was noted in rooting habit—the main roots of some striking downward and others spreading out just beneath the surface, mostly the latter. The varying forms may have been induced by local variations in fertility and mechanical composition. The main roots of one old tree penetrated to a depth of 3 to 4 feet, though smaller roots extended the feeding zone downward to about 15 feet. Roots ¼ to ½ inch were common at 12 feet. However, in this same orchard very few trees had main roots over 2 feet below the surface.

In an experimental nursery in this same soil, the roots of peach as well as of other stone fruit seedlings did not penetrate nearly so deeply as they did in clay loam soils at the Davis nursery. In sandy soil in an orchard near Wheatland, Yuba County, peach roots were not so large in diameter nor so deeply penetrating as was common in heavier types of soil in Santa Clara Valley, where comparable examinations were made. Near Rio Oso, Sutter County, peach roots in a very sandy soil, with alternating thin layers of silt, grew much more freely in the silty layers—developing whorls of roots in each of two, and sometimes three, alternating layers. In one spot where the surface sand was 12 to 18 inches deep above a thick layer of silt, the roots grew deeply; and the trees while young fared very well with but little irrigation.

Trees on any of these roots will usually grow well on lands with nearly pure sand or gravel surface profile, providing there are thick layers of silt or loam one or two feet below the surface. The reverse situation of a silt or loam surface with a thick layer of nearly pure sand or gravel beginning a foot or two beneath often produces poor growth.

An observation in regard to depth of planting of peach seedlings in very sandy and well-drained soils may be noted here. An inexperienced laborer at Delhi set some peach seedlings with the topmost roots (i.e. the root-crown) about two feet below the surface. These made as good growth as similar seedlings planted at the usual depth. Both lots were replants in an old peach orchard under excellent culture and irrigation. The owner states that even with budded peach trees in his sandy soil the young trees start better when planted deeply (bud union 6 to 8 inches below the surface), and no detrimental results have ever been noticed as the trees grew older.

Near Winters on the banks of Putah Creek apricot trees about 83 years of age, on peach roots, were washed out exposing a profile approximately 15 feet thick. The soil is a silt loam to this depth. Most of the root system was within 6 to 8 feet of the surface, though quite a number of roots were seen at 12 feet, and apparently very few got down to 15 feet.

In San Benito County young apricot trees were observed on apricot root planted in very sandy soil (in which, however, there was a silty layer several inches thick beginning about 6 inches below the surface). The trees had been planted quite deeply, and all the main roots grew upward and then spread out horizontally in the silty layer. In another nearby soil having a silty loam surface soil about 30 inches deep underlain with sand, none of the main roots of apricot, myrobalan, and Northern California

Black walnut penetrated into the sand. At Delhi, Merced County, in a soil having a thin silty surface layer, underlain with sand, the newly formed roots of long (12-inch) Marianna plum cuttings grew upward to the silt before spreading out horizontally.

In certain of the lighter, well-drained soils in the Brentwood district, the main roots, at least, of apricot on apricot roots penetrate more deeply than they do on either peach or myrobalan. Apricots on apricot root do well on the heavy soils here wherever there is good drainage, and they penetrate deeply wherever conditions are good for vigorous top growth.

A high water table has been observed to restrict root development to the surface layers, in many orchards where the soil was permanently saturated at depths below 3 to 5 feet, or where water occasionally rose near the surface during the winter. Myrobalan and other plum roots tolerate such conditions better than the others of this group. However, crown-rot fungi sometimes infect the trunks or root-crowns of plum roots at such times, especially when there is a thick layer of old leaves or dry grass around the crown. Even plum roots will not penetrate water-logged soils. In fact roots of such water-tolerant fruit species as quince will not grow down into water-logged soils.

One plum orchard on myrobalan root made fairly good trees and crops on a rather heavy soil with the water table approximately 2 feet from the surface during the growing season. A young, bearing peach orchard on peach root was observed on a sandy soil, with a water table kept down to about 2½ feet. The root system was shallow and anchorage so poor that stakes were necessary to prevent trees from blowing over.

Good orchards on peach, apricot, and almond roots have been observed in sandy soils where drainage ditches and pumps keep the water level down to 4 or 5 feet. Of the three, peach roots withstand these conditions best and almond most poorly. In hot, interior districts irrigation is usually advantageous, even when the water table is up to 4 or 5 feet. The greatest concentration of feeding rootlets is near the surface, and when old trees quickly exhaust the moisture above the water table the result is small fruits and trees of low vigor. In some areas of high water table the water may contain a sufficient concentration of alkali salts (see p. 22) to kill trees. In other areas a small amount may merely cause occasional "scorching" of leaves.

IV. TOLERANCE OF ROOTSTOCKS TO WET SOILS

Trees subjected to rise of water table, or to accumulation of irrigation or flood waters in low or poorly drained areas during the growing season, may suddenly wilt and die. If the waterlogging has occurred during the winter the trees may fail to leaf out in the spring, or they may come into bloom and even into full leaf before wilting. This condition is what growers commonly call "sour-sap" (p. 14) because of the sour odor of the dead root or trunk tissues.

There are two kinds of injury, and both may be present at the same time, in the same tree: (1) In the first kind, the lower parts of the root system are killed and turn dark. This root-killing is apparently due to a lack of oxygen and may perhaps be properly referred to as drowning, or suffocation. Perhaps under some of these conditions fungi or other organisms are able to attack living tissues of deeper roots. (2) In the second type of injury, the bark is killed by crown-rot fungi (p. 12) in a band at or near the surface of the soil, and the roots below may appear entirely normal. In this latter case the dead area about the crown may gradually enlarge, involving the root system below and progressing a short way up the trunk.

When both types of injury occur together in the same tree there will usually, at first, be a zone of live bark on the roots

between the two injured portions of the root system. Infection by crown-rot fungi during the dormant period can be caused by a much shorter period of exposure than is required for water-logged soil alone to kill them. A rootstock species may be relatively resistant to one of these two types of injury but sensitive to the other. This often makes it difficult to compare tolerance to wet soils of the four species of rootstocks in the orchards. For instance, many observations indicate that peach root is more readily infected by crown-rot fungi than is apricot root, but that peach root is more resistant to suffocation in water-logged soil. Thus in one district peach-rooted trees were the more severely affected, whereas in another trees on apricot root suffered the most injury. In the first case crown rot was the cause of injury.

In some conditions depth of rooting exposes some species to longer periods of submergence. Thus the main roots of almond usually penetrate much more deeply than do the others, with apricot next. This may be part of the reason that both are more sensitive than peach to injury or suffocation by water. Sometimes the injured trees come into full leafage in the spring, and then the leaves may have a "scorched" appearance, somewhat similar to alkali scorch. Presumably this is the result of poor uptake of water and possibly of some toxic materials produced in the affected root tissues.

Another complicating factor in the study of the relative susceptibility of these four rootstocks to "wet feet" is that sometimes there are alkali salts in the water. Trees on the four rootstocks vary in their susceptibility to alkali salts (p. 22). Though the main roots of myrobalan are shallow like those of the peach, yet they are inherently more tolerant of "wet feet." Also they are less susceptible to infection by crown-rot fungi. On the other hand myrobalan is quite sensitive to alkali salts, being about as sensitive as peach in this regard.

Unless some of these other factors enter into the matter, the tolerance of orchard trees to excess water appears to be in the following decreasing order: myrobalan, peach, apricot, almond.

In pot experiments (p. 21) apricot was more sensitive than almond roots to suffocation in water-logged soil, but it is possible that in orchards the deeper rooting of almond subjects them to longer periods of water-logging and thus makes them appear the more sensitive of the two.

Seedlings of a certain peach variety in Argentina are reported to have considerable tolerance to wet soils. Seeds of these have been secured, and the seedlings have been planted in wet soils for observation regarding their tolerance to "wet feet" and resistance to crown rot.

In general young trees are more susceptible to injury from excess water than old trees. However, many thousands of acres of mature trees have been killed. Trees with mild cases of root injury often recover, though obviously cases of crown rot cannot recover where the trunk is completely encircled (girdled) by the dead bark. With the crown-rot type of injury trees are sometimes affected only on one side, or there may be several small cankers distributed about the crown. Such trees may remain partially healthy, though observations show that wood rots get in through these wounds and the trees gradually decline in vigor.

Drainage furrows and ditches were sometimes effective in keeping the surface sufficiently dry, especially with trees on myrobalan roots. However, in the prolonged rainy season of 1941 these were often not effective with the other three rootstocks, especially on heavy soils—or even on light soils which had subsoil layers of such a nature that downward percolation of the rain water was not rapid.

A number of orchards on myrobalan root are growing normally, planted where there were permanent water tables from 2 to 3 feet below the surface, but in which

Fig. 6. Apricot tree, about 28 years, on myrobalan root on a sedimentary soil about 30 inches deep over a subsoil of heavy, poorly drained adobe. Tree partially pulled up showing the shallow root system developed under such conditions.

rise of the water table was prevented by drainage ditches and in some cases by supplementary pumping. The root systems of such trees were limited to a zone well above the water table, indicating that myrobalan roots cannot penetrate into water-logged soil. The photograph (fig. 6) at page top is of an apricot tree on myrobalan roots in such a location.

Mature trees in good health and production on peach, apricot, and almond roots on sandy, deep soils have been observed where the water table was kept down to 4 to 5 feet. In one case strawberry peaches on peach root were observed in such a situation in sandy soil with a water table only $2\frac{1}{2}$ to 3 feet deep; the trees were so shallow-rooted that bracing was necessary to hold them up against the wind. It is, of course, always a hazard on the part of a grower to establish an orchard even on myrobalan root where the water level is close to the surface. There is danger of crown-rot infection should the surface soil remain wet over too long a period. Also the feeding area of the roots is quite limited in comparison to soils in which the roots can penetrate to greater depths.

The most extensive killing of trees of the stone fruits has been along the rivers of the Sacramento and San Joaquin Valleys where, at flood stage, adjacent lands are either inundated or there is a rise of the water table up into the root zones of the trees. This does not occur every year nor at regular intervals. The flood stage may come any time during the winter or late in the spring when the snow in the Sierra Nevada Mountains is melting rapidly. Smaller areas in many districts in the state are also occasionally affected, not necessarily from river overflows, but from long, rainy spells which water-log the soil in poorly drained areas and in lands having subsoils which do not allow rapid downward percolation of rain water.

Extensive damage from excess water in the soil occurred in the spring in 1921, 1927, 1928, 1938, and 1941. At these times the author made many observations regarding rootstocks concerned and the nature of the injury. The largest number

of trees were killed in 1938 and 1941. In the entire state in these two years approximately 10,000 acres of trees were killed—chiefly prune, peach, apricot, and almond. In 1938 most of the tree injury was caused by crown rot rather than by dying of the main and deeper roots, whereas in 1941 both types of injury more commonly occurred on the same tree.

In the Colusa district, where in 1938 about 200 acres of French prunes on myrobalan root were killed, the damage was almost entirely from crown rot. In one orchard young myrobalan-seedling replants in orchards were apparently as readily injured as the old prune trees on this root. The position of the graft union in relation to the soil surface (whether beneath ground or high above) apparently did not influence the susceptibility to injury. The crown rot canker often did not extend upward to the graft union.

Myrobalan-rooted trees will tolerate submergence in running water, at least during the winter, spring, and early summer, for a much longer period of time than they will in standing water or in water-logged soil. This has been noted in the case of French prune trees on this root a number of times in the flooded areas along the rivers of the interior valleys. One orchard was subjected to running water for 6 months, beginning December 2, 1937. Very few trees were injured in higher areas, where the soil became completely exposed and the water ceased running into the orchard about June 2. However, in low spots the trees seemed injured by the stagnant water after the flood had abated, for the leaves remained as green as those on the higher ground for a week or more after the water stopped running. This orchard was on very sandy, well-drained soil. The uninjured trees bore a fair crop of fruit in 1938, though the terminal growth was much retarded. At the time the writer first visited this orchard (May 18) the depth of running water on the highest elevations was estimated at 5 feet. The leaves were then slightly yellowish but uninjured trees soon became normally green after the water had drained away.

In several other orchards in this same season French prune on myrobalan root, trapped in stagnant water holes from flood water of the previous months, were observed to die as early as April.

Notwithstanding their comparative tolerance to excess soil moisture myrobalan-rooted trees when transplanted from the nursery into wet soil in the orchard may fail to start new roots and may show evidences of "souring," or they may become infected with crown-rot fungi. It is likely that low temperatures and low oxygen content deter new root growth.

Marianna and St. Julien plum roots seem as resistant as myrobalan to excessive soil moisture. There is some evidence that the Marianna root is more resistant, but further observation is necessary to establish this point.

In experiments at Davis with seedling trees of myrobalan, peach, apricot, and almond, growing in sand in 5-gallon cans, there was no damage during the dormant period from keeping the soil saturated with water. Trunks and root crowns had been treated with Bordeaux paste to prevent infection from crown-rot fungi. On March 10, after 77 days of submergence, a few of each kind were taken out of the saturated soil and transplanted into damp sand. New roots several inches long were present on all the trees at the time they were taken out of the cans, and all of them grew normally. A similar set was taken out on March 20 (87 days). The apricots failed to grow, and the Lovell peach and almond seedlings started new growth only at the bases of the main roots, near their attachment to the root crown. Shalil peach and myrobalan seedlings started new root growth even at the tips of the small rootlets. Of the set taken out on the hundredth day only the myrobalans survived. The latter were in leaf and showing slight signs of distress. The

remaining myrobalans were taken out of the saturated soil on April 20 (118 days), and these were soon growing normally.

Experimental work by Marth and Gardner (1939) in Maryland indicates that seedlings of the various varieties of peaches show a difference in tolerance to root injury from excess water during the growing period. Of the California varieties, seedlings of Shalil were much more tolerant than those of the Southern Naturals, Elberta, and Muir. Unfortunately, seedlings of Lovell were not included in their tests.

The influence of the scion variety has been noticed in a number of graft combinations. Thus Ne Plus Ultra and Peerless almond, whether on peach or almond roots, are more resistant than is Nonpareil. Texas and IXL are also more sensitive than Ne Plus Ultra and Peerless, but not so much so as Nonpareil. The cases noted were mostly, if not all, of the crown-rot type of injury, yet the disease was often far below the graft union. In the Brentwood section both in 1938 and 1941 it was observed that Tilton apricots, whether on peach or apricot roots, were more subject to injury than were Blenheim. In this district almond varieties on peach-seedling roots were more resistant than apricot and peach trees on peach root.

In several orchards in the Sacramento Valley it was noted that French prune and plums on peach root were more resistant than peach varieties on peach root. Duarte plums on myrobalan root in two orchards were more severely injured than nearby French prune on this root. In one orchard Imperial and Robe de Sergeant prunes on myrobalan root were more sensitive than French prune on myrobalan root.

V. RELATION OF ROOTSTOCKS TO LIME, ALKALI, BORON, ZINC, AND POTASSIUM

Tolerance to excess lime. Trees on almond root in soils of high lime content or with marly layers near the surface are not so subject to chlorosis from iron deficiency as they are on the other roots of this group. Those on myrobalan root are next in order of tolerance. Trees on the latter root seldom become entirely chlorotic—usually developing some yellowish leaves only at the tips of the branches in late summer. Trees on apricot root are next in order, and those on peach root are more subject to lime-induced chlorosis than any of the four.

In one area in Santa Clara Valley the roots of prune trees on almond root were observed to spread out fan-like upon the top of a marly layer which was 2 or 3 feet below the soil surface, yet the trees were without severe chlorotic symptoms. In the Paso Robles district almond trees on peach were observed to be doing poorly on limy soils, whereas those on almond root were performing normally in the same areas.

Tolerance to excess alkali salts. All the rootstocks of this group of stone fruits are sensitive to alkaline soils and water containing an excess of alkali salts. Trees on almond root seem to be the most tolerant, followed in order by roots of apricot, myrobalan, and peach, there being very little difference between the two latter. In some soils of slight alkalinity almond on almond has been sufficiently tolerant to enable the trees to produce profitable crops, whereas those on peach root were not thrifty.

This difference in alkali tolerance might possibly explain a few reports of growers that their almond varieties on almond root were less injured by a rise in water table than were those on peach, in spite of the fact that the latter are known to be the more tolerant to excess water. These latter reports were from districts where the free ground water is often rather high in alkali salts.

Observations of seedlings grown from seeds of a peach-almond hybrid (p. 49) indicate that it also has more tolerance to alkali than peach and myrobalan. How-

ever, there are no common almond rootstocks nearby to indicate whether or not they are more or less tolerant than these.

It is likely that the scion variety has considerable influence on sensitivity to alkali, but the extent of this influence, if any, needs further study. An outstanding example is Texas almond, which is, as reported by Lilleland (1945, 1946), more susceptible to leaf scorch due to alkali salts than are other almond varieties; and this occurs regardless of whether it is on peach or almond root. Though this susceptibility may be entirely a leaf characteristic, yet it brings up the question regarding the tolerance of the roots of seedlings of the Texas variety, which are now widely used for nursery planting.

In some alkaline situations apricot varieties on myrobalan root are more readily injured than are those on apricot root, and in one area those on peach root were more sensitive than those on apricot. In two areas Tilton apricot was more sensitive than Blenheim to high water table, but in only one of these was it determined definitely that the water contained alkali salts.

One factor which complicates the studies of these phenomena is the chemical composition of the alkali salts. Hayward, Long, and Uhvits (1946) found that Elberta peach on Lovell peach-seedling roots seems preferable to Elberta on Shalil peach roots where these trees are subjected to moderately saline conditions. They also observed that chloride salts are more toxic than sulphate salts. Some observations indicate that sodium carbonate is as injurious as chlorides—perhaps even more so. However, these two salts so often occur together that it is difficult to study their separate effects in orchards. Lilleland[10] reports that in certain situations excess carbonates cause leaf symptoms which indicate that manganese is not taken up from the soil in sufficient quantity in the presence of excess sodium carbonate. Peach trees on peach root (probably Lovell seedlings) were more severely affected by carbonates than those on apricot root (probably Blenheim seedlings).

Tolerance to excess boron. In experiments at the Davis Station, Hansen (1948) has shown that French prune on apricot, peach, and Marianna plum roots takes up boron from the soil more freely than it does on roots of almond and myrobalan plum; and in turn that trees on almond root seemed to take up less boron than trees on myrobalan. He concludes that "almond root is suggested for those locations where excess boron is a problem and where other soil conditions are favorable. If the soil is too heavy or wet for almond root it is suggested that myrobalan plum be used." Trees also suffer from a deficiency of boron, but no observations have been made regarding the relation of such a deficiency to rootstocks of stone fruits.

Relative tolerance to zinc deficiency. Small leaves with yellow mottling and die-back of twigs may be caused by lack of zinc in the soil. Rootstock relations to this trouble are apparently slight and seldom noticed. In one orchard young Santa Rosa plum trees on Shalil peach root required zinc treatments, whereas those on Marianna root, in adjoining rows, showed no evidence of the disease. In another orchard Santa Rosa plum trees on myrobalan root were affected, whereas those on apricot root showed no signs of distress.

Rootstock relations to potash deficiency. The soils of some large areas in the Sacramento Valley, and some smaller areas in other sections of California, are low in available potassium. Lilleland (1932) has shown that prune trees under these conditions cannot mature large crops of fruit without serious effects upon the health of the trees. The leaves "scorch" around the edges, and the ends of the limbs may die-back. The upper

[10] Personal communication by Omund Lilleland, College of Agriculture, Davis, California, 1949.

sides of the large branches become sunburned and later infested with flat-headed and shot-hole borers. Prune trees in the Sacramento Valley tend to bear more heavily on peach and almond roots than on myrobalan. In those areas where available potassium is low, trees on the two former roots are therefore more susceptible to this trouble, and may die after a few years of heavy cropping. Those on almond root are more severely affected than those on peach.

French prune on Marianna plum root sometimes tend to overbear and therefore perhaps are a greater risk in potassium-deficient areas than are those on myrobalan plum. There are no prune trees on Marianna seedling Selection 2624 old enough on these soils to compare with those on myrobalan root.

VI. TOLERANCE TO SOILS PREVIOUSLY OCCUPIED BY FRUIT TREES

California nurserymen have long recognized that not more than one or two crops of nursery trees of peach, apricot, and cherry could be grown satisfactorily on the same site—even though it were virgin soil at the outset. It has also been observed that nurseries of these species could not be successfully grown where orchards had been removed even many years previously. At the experimental nurseries at the Davis Station seedlings of almond and myrobalan grew fairly well following mature plum trees (which were on myrobalan roots) though peach and apricot seedlings grew poorly.

It is a very common experience of orchardists that young fruit trees often do not grow well when planted in soil previously occupied by orchard trees. If the new tree is a "replant" where a tree has been removed in a mature orchard, part of the difficulty is competition with the roots of the older trees for moisture and soil nutrients, and extra care in supplying additional applications of water often results in more rapid-growing replants. In some cases nitrate fertilizer has apparently been of assistance.

Replants of trees on almond and myrobalan roots in old orchards have been observed to grow much better than replants on peach and apricot roots. The use of the very vigorous Myrobalan 29 (p. 28) as a replant has been very successful in Sonoma County, even in old prune orchards on myrobalan root. The trees are top-worked to prune after they have grown several years in the orchard. By this method they develop into bearing trees many years sooner than do nursery-budded replants on myrobalan root.

Near Hollister, San Benito County, California, Blenheim apricot trees on apricot root grew very well following an old apple orchard.

The most common difficulty has been in following old orchards on peach root with new plantings (or single replants) of trees on peach root, but this deterrent effect has not always been evident. Gilmore (1949) has found this difficulty more common in sandy than in heavy soil. In any case it is safer to replant if feasible with a rootstock of a different species from that originally used.

Proebsting and Gilmore (1941) of the California Agricultural Experiment Station have found evidence that some toxic substance produced from the bark of peach roots at times restricts the growth of trees on peach root planted where old peach orchards have been removed. In an orchard in Sutter County where peach trees on peach root were planted on land previously occupied by old peach and cherry trees, those in the cherry area grew more normally than did those on the part previously occupied by peach on peach root. In another orchard peach trees were planted where old pear and peach trees had been removed. Those following pear grew much more thriftily than the ones following peach. At the Davis Station old apple and peach trees were removed and the land replanted to Fay Elberta on peach root. The latter planted in the

former peach area grew poorly, while those following apple grew normally.

In a Winters orchard apricot trees were planted on apricot and peach roots in alternate rows, in land from which very old peach trees had been removed. Those on apricot grew very much more thriftily than did those on peach root. Yet in virgin land in this area apricot on peach grow as vigorously as those on apricot root.

In some areas a high population of nematodes (either the root-knot or the lesion nematode or both) has been built up in old orchards, and replanting of these with trees on rootstocks susceptible to these organisms may give disastrous results.

VII. MYROBALAN AND OTHER PLUM STOCKS FOR STONE FRUITS

Plum roots are most commonly used for plum and prune varieties, though under special conditions they are employed for apricot and almond and more rarely for peach. In California the myrobalan or cherry plum (*Prunus cerasifera*) is the most common one in use, but Marianna and vigorous selections of this plum are often used for special conditions. Although the myrobalan is usually propagated by seed, in recent times vigorous selections have been grown by stem cuttings. The Mariannas are propagated by cuttings only.

Ways of distinguishing plum roots from the roots of other stone fruits in the nursery are discussed earlier (p. 5).

In early times Damson and St. Julien plum roots were used in California. Some plum and prune trees were also produced on their own roots from suckers, but these were difficult to propagate and were apparently not entirely satisfactory. Peach roots were next used and later St. Julien and Damson seedlings. Finally the myrobalan was introduced. Today the only plum trees which we know to be entirely on their own roots are some French prune orchards near Healdsburg, Sonoma County. The following plums produced by layering grew more slowly in the orchards at Davis than those on myrobalan and peach roots: Wickson, Jefferson, Climax, Clyman, Green Gage. Santa Rosa can be grown by cuttings, and the trees grow normally in the orchard. At six years of age the fruits of Climax on its own roots were noticeably large and of good quality.

Though we have occasionally seen Japanese plums, especially Duarte, Beauty, and Santa Rosa, form substantial scion roots above the graft union, we have not found any mature trees of these varieties budded on seedlings of Japanese plums, as is common practice in China and Japan. In experimental plots we have a few French prune trees 4 to 5 years of age, which are growing quite well on Santa Rosa and Wickson seedlings. Since the European plum and prune varieties do not usually grow well when top-worked upon Japanese plum trees, it is doubtful if they would continue to perform well upon Japanese seedling roots, though budded at the ground level.

In England and Europe several other plum stocks, largely produced by layerage, are in use. The East Malling Research Station in England has long worked with these. In 1923 the California Agricultural Experiment Station secured from them the following: Brompton, Pershore Egg, Willingham Gage, Warwickshire Drooper, Brussels, Common Plum, Bastard Victoria, Bastard Orleans, Blaisdon Red, Broad-leaved Shining Mussel, Common Mussel, St. Julien A, B, C, D, E, and G, Black Damas (Damson) A, B, C, and D. Tests so far indicate that these rootstocks have no merit over ordinary myrobalan seedlings for orchard use in California, but some are being tested for resistance to certain diseases and soil conditions.

At the East Malling Research Station, Hatton (1936) reports that for semidwarf trees for home gardens Pershore Egg is one of the best stocks, with Com-

mon Mussel and Brompton next in order. These European plum stocks belong to the species *Prunus domestica* and its variety *insititia* and are apparently hybrids of two or more wild plums. They are not known in the wild. Crane (1935), of the John Innes Horticultural Institution in England, indicated there is strong chromosomal evidence that the domesticas are a cross between myrobalan (*P. cerasifera*) and Blackthorn (*P. spinosa*). He states, "The results of our investigations at Merton lead us to the conclusion that the diploid species *P. cerasifera* and the tetraploid species *P. spinosa* are involved in the origin of our domestic plums. A cross of diploid by tetraploid accompanied by chromosome duplication would give a hexaploid such as *P. domestica.*"

The Marianna plum and selected seedlings of this variety are discussed on page 33. Roots of more than 100 plum varieties and species are being tested in orchards for resistance to oak-fungus root rot (p. 9). Many of these have been top-worked in the orchards to various plums, prunes, and apricots.

Other plums under test as rootstocks at the Davis Station which may be useful for certain purposes are: *P. bokhariensis* from India (several strains, one of which closely resembles Marianna); Methley (myrobalan × Japanese plum)—(Propagated both vegetatively and by seed, it is quite vigorous.); *P. spinosa* (several hybrids with *P. domestica*); Etters Giant and Etters Best—reported by the late Albert F. Etters, Ettersburg, Humboldt County, California, to be crosses which he made between the Sierra plum, *P. subcordata,* and Golden Drop, *P. domestica;* Marianna and several selected vigorous seedlings of this latter variety which propagate readily by cuttings. The use of plum rootstocks for apricots, peaches, and almonds is treated in later sections.

The myrobalan plum. Seedlings of this species have been satisfactory as a rootstock only for plum, prune, and—under certain conditions—apricots. They have been only partially successful for almonds, and hardly at all for peach varieties.

Until quite recently practically all of the myrobalan plum seeds and seedlings used in California were imported from French dealers, who in turn procured them from Italy. Myrobalan is probably native to the Caucasus Mountains and to Persia and the Southwestern areas of Asia. At present, practically all seeds of this species are locally grown from seedling trees. Some California nurserymen grow their own seedlings, while others buy them from nurserymen in Oregon and Washington who specialize in growing seedlings.

Myrobalan seeds for nursery purposes have usually been gathered from seedling trees which vary widely in vigor, grafting affinities, growth habits, root distribution, and other characteristics. It is therefore difficult to analyze accurately the results of their use by growers as stocks for some of the stone-fruit varieties under the widely differing climatic, soil, and cultural conditions prevailing in California. It is remarkable how uniform in size and general behavior are some varieties on this root in orchards located on deep uniform soils. Of course in the nursery there is a natural elimination of the dwarfish types at budding time. Again when they are dug up in the nursery the trees are graded and sold according to rather strict measurements. It is not impossible that this sort of standardization has been a factor making for uniformity of the trees within an orchard. There are exceptions to this uniformity. For instance the Robe de Sergeant prune is apparently not congenial with all myrobalan seedlings, and the trees in an orchard are therefore often quite variable in health and vigor. Kelsey plum and apricots show this same behavior toward myrobalan roots but to a lesser degree.

Owing to the great variation in seedlings, it is impossible to describe the my-

Fig. 7. Branch and fruit of a typical myrobalan plum, Prunus cerasifera. Note the small round fruits and the slightly folded and recurved leaves. Fruits of some seedlings are a little longer (oblong) in outline.

robalan accurately. The fruits (fig. 7) are small and spherical like cherries and vary in color from tree to tree, being mostly either yellow, red, or reddish-purple when ripe. The twigs are more slender than those of European plum and prune, and the leaves are rather small and thin, usually light green, short-ovate, short-pointed, and finely serrate. Although usually folded upward along the midrib the leaves are sometimes flat. The trees are often thorny, but some strains are nearly smooth-branched. Some seedling trees are dwarfish, while others grow rapidly to large size. Purple-leaved strains of myrobalan include the ornamental varieties *Pissardii, nigra,* and *Moseri flore-pleno* and their hybrids with the common myrobalan. A number of hybrids of myrobalan with other plums are in cultivation; Marianna is apparently a cross between this and the Wild Goose plum (*P. munsoniana*) of the southern states. Methley and Banana are evidently crosses with myrobalan and Japanese plums. Both seedlings and vegetatively grown trees of these two latter varieties made vigorous trees in test plots at the Davis Station.

The myrobalans bloom and come into leaf with the Japanese plums, considerably earlier than the European plum varieties.

At the Davis Station approximately 250 selected seedlings of myrobalan have been tested as a source of seed. Some were selections of vigorous seedlings from both our own and commercial nurseries; others were selected by the late Dr. W. L. Howard in Italy, England, and France in 1921 and 1922. A few yielded seedlings which seem superior to others in vigor and ease of production by stem cuttings. They have been given identifying numbers and are being tried out as rootstocks for varieties, for resistance to certain diseases and insects, and for suitability to various soil conditions.

Several myrobalans (U. C. Selections 3J, 2–7, and 5Q) show particular promise as sources of seed for nursery work, giving high germination and uniformity in

size of seedlings in the nursery. Seedlings of Myrobalan 3J are smaller in the nursery row than the others; yet apricot, plums, and prunes budded upon it make excellent growth in the orchards where it has been used.

Whether the very vigorous selections will produce larger or healthier trees in the orchard over a period of years remains an unanswered question. A number have been budded to French and Robe de Sergeant prunes in test orchards, and some are now 10 years of age. To date, in these plots the myrobalan from seeds have not made better rootstocks than selected ones propagated by cuttings. The Robe de Sergeant prune, which is not congenial with all myrobalan seedlings, grew more vigorously on certain strains grown by cuttings than on several myrobalan seedlings in the same planting. The most vigorous myrobalan selection observed is Myrobalan 29, introduced by Gregory Brothers Nursery, Brentwood, California. It is produced by stem cuttings and is resistant to the root-knot nematode. Originally it was a mixed population of several very similar strains, but the better ones have been isolated and given distinctive numbers, 29C, etc.

Observations indicate that vegetatively grown vigorous myrobalan strains, planted in orchards where trees have died, grow more rapidly than budded trees on myrobalan seedlings. When these are top-worked to the desired variety a large, bearing tree is produced more quickly than when nursery-budded trees are used.

It has been noted many times that in soils where a nursery or an orchard has been recently removed myrobalan and almond seedlings grow much better than do those of apricot and peach.

The myrobalan has a wide range of adaptation to soils and climates. In common with other plum roots used as rootstocks, it can endure heavy soils better than the other rootstocks in common use for stone fruits in California. This may be largely due to its greater tolerance of excess soil moisture and resistance to crown rot. It also does well on light and sandy soils. In fact, like the other rootstocks, trees on it usually do better on light than on very heavy soils.

The main roots of the myrobalan are not normally large in diameter nor particularly deep-penetrating, tending like the peach to spread out horizontally. In previous sections comparisons are made with the other rootstocks regarding depth of penetration in the soils, disease and insect resistance, and tolerance to excesses of alkali and other chemicals.

Vegetative propagation of plum stocks. Marianna and some myrobalan strains are propagated successfully by stem cuttings, though none of those tried by root cuttings gave a good stand of nursery trees. Root cuttings produced a root system more nearly like that of a seedling, while roots from stem cuttings all emerged from the base of the cutting and usually spread out horizontally for some distance before striking downward.

Whether myrobalan strains grown vegetatively by cuttings have a place in California orchards has not been fully determined; in special cases they may be desirable. For instance, plum and prune varieties which do not grow well on all myrobalan seedlings may possibly be found to perform better on some selected myrobalan strain which could be propagated by cuttings; or certain strains may be found more adapted to certain soil conditions, or resistant to certain diseases or pests such as oak-root fungus, insects, and nematodes.

A better stand has been attained from cuttings planted in the lath house than in the field—possibly because of better control of soil conditions. Horizontal rooting is largely remedied by pruning the roots back to about ¾ to 1 inch long before transplanting the small rooted cuttings to the nursery the following year.

A number of ungrafted vigorous myrobalans have been planted in orchards

where trees have died out. These are later top-worked to the desired varieties, usually after they are 3 or 4 years old.

Plum and prune varieties on plum roots. Almost all the Oriental and European plum and prune varieties seem congenial to the myrobalan root. President, Kelsey, and Robe de Sergeant—particularly the latter two—are not entirely satisfactory.

The French (Agen, d'Agen, Petite) prune has been grown extensively in many soil and climatic environments throughout California for over 80 years. Hence it affords valuable material on the adaptability of the rootstock species to various conditions, for besides myrobalan the French prune has been grown on peach, apricot, almond, Marianna, St. Julien, and several other plum roots—and to a very limited extent on its own roots from suckers growing from scion roots above the graft union. The experience with French prune on these rootstocks should give some indication as to the differential performance of other stone-fruit varieties upon them, under similar soil, climatic, and cultural conditions, provided the graft combination is congenial.

It has been variously estimated that 50 to 75 per cent of the prune orchards in California are on myrobalan seedling roots, the rest mostly on peach. The choice of myrobalan root has probably been due largely to its wide range of adaptation to soil, moisture, and climatic conditions. On this root the prune varieties not only endured light soils, but on heavy, wet soils they performed better than on almond, apricot, and peach roots, and they survived drought in unirrigated soils better than any except the almond root.

Opinions differ among growers as to the preferable rootstock for the French prune, not only in different districts but even within a given geographical environment. This is due partly to variations in soil, irrigation, and cultural practices, and to the incidence of disease and insect pests.

In unirrigated orchards north of San Francisco Bay, the myrobalan root is now generally used. Many growers in these districts report that if it were not for the crown-gall disease almond root would be preferred, except in low, wet ravines. This disease is so common here that many trees in an orchard planted to such susceptible roots as almond fail to grow thriftily. Those trees on almond root which do escape serious infection by this disease grow faster, bear earlier, and produce larger fruits than those on myrobalan. Trees on almond root are more drought-resistant than those on myrobalan, and those on peach root are less drought-resistant than either of them.

In the Sacramento Valley most of the older prune orchards are on myrobalan and peach roots, a few on almond and Marianna. The trend in recent years is toward myrobalan and one of the vigorous Marianna selections. In this area all varieties of prunes on peach and almond bear younger and more heavily than those on plum roots. Many of the soils here tend to be deficient in available potassium, and heavy crops subject the trees to serious leaf-scorch and die-back on these roots.

The status of French prune trees on Marianna root is still uncertain in areas deficient in potassium. Apparently the regular thinning of plums and larger varieties of prunes to meet market requirements prevents overbearing and the accompanying die-back of these fruits. Experiments by Lilleland (1932) in thinning French prunes indicate that this practice would prevent die-back in these trees, and also that heavy applications of potassium sulphate will partially correct this condition.

French prune has been tested on 25 different rootstocks. Though it did well on most of these, yet none proved any better than the ones long in use. At Davis there is a test plot of French prune 10

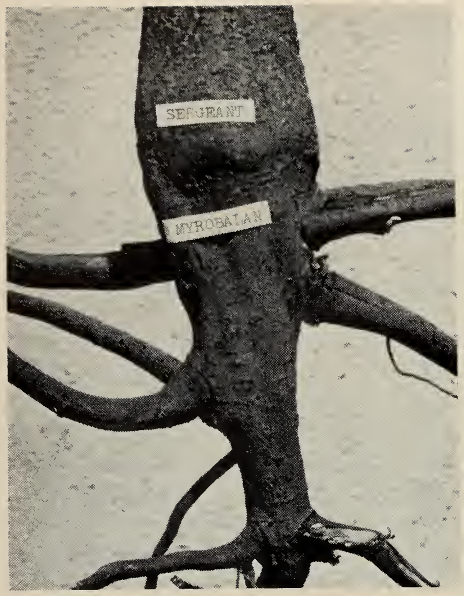

Fig. 8. Pinch or carrot root. Robe de Sergeant on uncongenial myrobalan seedling. The scion is growing faster than the root; the latter is growing dwarfishly and tapers rapidly downward.

years of age on 11 rootstock species and selections.

Occasionally with French and Robe de Sergeant prune, the myrobalan root fails to develop as rapidly as the scion trunks, causing what growers call "pinch root" or "carrot root" (fig. 8). Hendrickson (1926) found evidence that the seedlings of certain strains of myrobalan might behave in this way with French prune. In early-day horticulture in California, growers and nurserymen reported cases where trees behaved in this manner when the myrobalan stock was propagated by cuttings, and it became quite a common tradition that myrobalan roots propagated by cuttings made weak trees. It is likely that the strain from which cuttings were taken was at fault rather than the method of propagation, for we have had test trees in which alternate rows of French prune on myrobalan seedlings and myrobalan cuttings showed no difference in growth and bearing habit at 10 years of age. Apparently pinch root of French prune on myrobalan is not always due to the rootstock. A number of cases have been observed where groups of trees have developed in areas of irregular contour in orchards otherwise growing normally. The irregular form of these areas suggests some soil condition as sometimes contributing to pinch root in French prune on myrobalan. It has been observed in both light and heavy soils.

Robe de Sergeant prune is not entirely compatible with myrobalan; this seems to vary from seedling to seedling so that often there is a great diversity of size and health in orchard trees of the same age. The small ones are usually found to have a dwarfish, carrot-like root system, or else the unions are rough and enlarged. Both pinch root and bacterial gummosis (especially the sour-sap form) are so common to Robe de Sergeant on myrobalan root that growers generally consider this root unsuitable to this variety. Trial of the more vigorous Myrobalan Selection 29 and of the vigorous Marianna Selections 2623 and 2624 over a period of 12 years indicates that this variety performs satisfactorily on these stocks. Robe de Sergeant does poorly on peach and almond roots. Two trees at Davis performed fairly well on apricot root, though they tended to overbear, causing serious die-back.

Sugar prune performs satisfactorily on myrobalan, apricot, and almond, but not on peach root. The variety is prone to overfruitfulness, and thus gets into the alternate-bearing habit. In one orchard near Morgan Hill bacterial gummosis was observed to be much worse on Sugar prune on myrobalan than on apricot root.

In several Sonoma County orchards, *Imperial* prune on myrobalan was observed to be more subject to bacterial gummosis, and especially the sour-sap type, than on peach root. In general this variety does not do very well on peach root, and most growers prefer it on myrobalan. Tragedy and many other plums,

planted in Capay Valley, Yolo County, in the early days without irrigation, bore larger fruits when young on peach than on myrobalan roots. However, on the latter they withstood dry years better and were longer-lived. Imperial prune does better on myrobalan than on peach in the Sacramento Valley. In that region it bears too heavily on peach, causing early decline of the trees.

In the Sierra foothill sections of Placer and El Dorado counties, most growers seem agreed that plums on myrobalan tolerate non-irrigated conditions or too prolonged delay of irrigation in the summer better than do trees on peach root. Nevertheless, for irrigated orchards in these districts growers have largely abandoned myrobalan in favor of peach root except in low, wet situations. The trees are said to grow more rapidly and produce larger fruits on peach, and some growers believe the fruits ripen a few days earlier on this root. Also the trees are much freer from bacterial gummosis on peach root.

In Tulare County, Duarte plums seem to do better on myrobalan than on peach root, while President does as well on peach as on myrobalan. Marianna plum roots are used in sandy soils where the root-knot nematode is serious. Generally speaking, Kelsey plum does well upon myrobalan seedlings, but there are individual myrobalan seedlings with which it is not compatible. The one shown in figure 9 is an example of the latter. It was restored to normal vigor and production by planting apricot seedlings beside the tree and grafting their tops into the trunk of the Kelsey tree.

Aside from the above-mentioned cases, all plum and prune varieties tried upon myrobalan seem to thrive. Also myrobalan has been successfully top-worked upon many varieties of plum without revealing any incompatibilities. On page 69 is a table comparing the behavior of 164 plum and prune varieties on myrobalan, peach, apricot, and almond roots; and in the sections dealing with peach, apricot, and almond roots further comparisons are made between these and myrobalan root. Some of the information in this table was obtained from a mature Davis orchard where 43 common varieties were growing on these four rootstocks on a deep, well-drained Yolo clay loam.

Growers often report that plums and prunes ripen a few days earlier on peach than on myrobalan root. At the Davis Station the writer (Day, 1933) collected data on the ripening dates of Grand Duke plums on the four rootstocks and on grafts upon Formosa and Wickson plums and upon peach varieties. On the different rootstocks there was only 1 to 2 days' difference in ripening time, varying from year to year. However, those top-worked upon the Japanese varieties (Formosa and Wickson) always ripened 2 to 3 days earlier than those on seedling roots of myrobalan, peach, apricot, and almond.

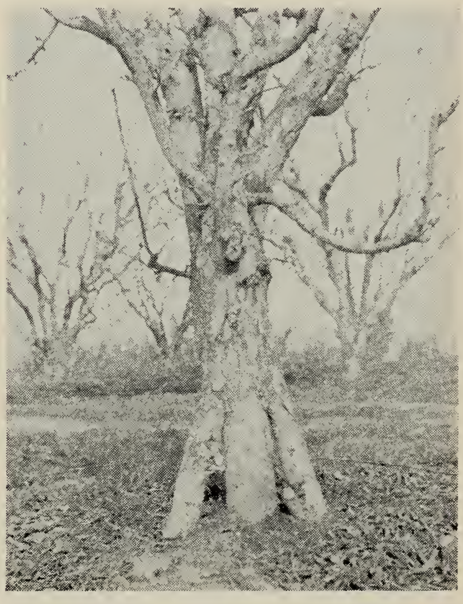

Fig. 9. Apricot seedlings were planted beside this ailing Kelsey plum tree (on myrobalan root) and the tops grafted (inarched) into the Kelsey trunk. The Kelsey tree was restored to normal vigor and fruitfulness.

Other plum species used as rootstocks. A few very old French prune orchards on Damson and St. Julien plum roots have been observed in the coastal districts of Central California. The trees were healthy and of normal size. They were more prone to suckering from below the bud union and from roots cut by the plow than are trees on myrobalan root. French prune on some undetermined type of St. Julien and on Common Mussel, 20 years old, on unirrigated soils near Vacaville were dwarfish, and root suckering was profuse.

No observations are on record on soil preference and depth of penetration of the St. Julien root in California. In "Plums of New York" (1911) Hedrick states, "Plum growers who have had experience with plums on several stocks are almost united in the opinion that the St. Julien is the best of all for the Domesticas, at least." In more recent publications Hedrick (1923, 1932) places myrobalan seedlings ahead of St. Julien for plums in that state, saying of the latter, "It is commonly believed that the trees on this stock are very vigorous, hardy, long-lived, sucker but little from the roots, and are adaptable to many soils."

According to Van Riper[11] of the University of Bordeaux, France, St. Julien is not so commonly used as a plum stock as is the Damas (Damson type). Also it has some dwarfing tendency as compared to myrobalan.

At the Davis Station Giant, Burbank, and Beauty on Florida Sand plum (*P. angustifolia*) were recently pulled out at 16 years of age. They were small for their age, very productive, and healthy. Apparently seedlings of this species would make good dwarfing stocks for plums in gardens and for espalier training.

At the Davis Station several varieties of plums and prunes have been tried on roots of 15 vegetatively propagated European plum rootstocks selected by the East Malling Research Station, England, and on a number of strains and species of our own selection. In these plantings St. Julien G is the only one of the St. Julien group given to excessive root suckering between the rows and about the trunk.

Prunus bokhariensis appears to be very vigorous and especially deep or taprooted. One strain (S.P.I. 40229) has fruits and growth habits similar to the Marianna plum, but is not resistant to the root-knot nematode. Its usefulness as a rootstock for plums and prunes has not been fully evaluated. French prune trees 10 years old seem to be doing as well as those on myrobalan in the same plot.

Methley plum (S.P.I. 31652) is probably a cross between Satsuma and myrobalan. Both seedlings and rooted stem cuttings grew very vigorously. Some of its seedlings are resistant to the root-knot nematode. It has considerable resistance to oak fungus, but is very susceptible to crown gall.

French prune is dwarfish on the native Sierra plum, *P. subcordata* (Pacific or Western plum), which itself never becomes very large in the wild. At Davis it bears so heavily that thinning of the fruits is necessary to prevent dieback conditions. The success of the union of the 20 selections of Sierra plum growing on myrobalan root indicates that possibly some of the domestic plums should grow upon it, even though dwarfishly. It grows well on both myrobalan and peach seedling roots. In a 10-year-old orchard of selected Sierra plums at Lakeview, Oregon, those on peach root have grown more rapidly than those on myrobalan. Roberts and Hammers (1951) of the Oregon agricultural experiment station suggest the use of peach root for this plum. In one part of a natural "grove" irrigation increased the size of trees and fruits and improved flavor and fruitfulness. Successful top-working of French prune and Burbank plum to this species has been observed.

[11] Letter of August 10, 1938, to the author from Charles A. Van Riper, University of Bordeaux, France.

In oak-fungus test plots in eight counties, French prune has been top-worked upon over 100 strains of myrobalan, Marianna, and other species. These are yielding useful information regarding the grafting affinities of French prune.

French prune on its own roots. Several growers near Healdsburg, Sonoma County, have for many years been using rooted French prune suckers for replants in their orchards. A few of these, 25 to 30 years old, are claimed to bear such large crops and so regularly that they must be carefully pruned to keep the fruit up to the most profitable size. Growers believe that they tolerate drought conditions better and are less affected by crown gall, gummosis, and possibly oak-root fungus than trees on myrobalan roots. In one orchard in 1938 they were not so resistant to prolonged wet-soil conditions. Whether the trouble was root drowning, crown rot, or bacterial gummosis was not determined. Resistance to natural infection by crown gall seems well authenticated, but there is doubt about its having enough resistance to oak-root fungus to make it valuable in that regard.

The tree usually grows rather slowly the first year or two after planting, but thereafter it grows at a normal rate to mature size. Rooted suckers must be held in the nursery one to two years to develop a large root system; otherwise they grow very poorly. Above, right (fig. 10) is a photograph of a French prune tree about 15 years old on its own roots.

Van Riper* states that the French prune is propagated in France mostly from root suckers rather than being budded onto nursery seedlings. From other reports we find this is an old practice there. However, Lake (1901) reported that the "common stock for Agen is the St. Julien; for the 'Quetsches' (German prune of America) St. Julien and White Damson; for the Mirabelle, St. Julien and myrobalan."

* See footnote 11, page 32.

Fig. 10. French prune on its own roots, 15 years of age. Propagated from root suckers arising from roots that grew from above the graft union of a French prune tree on deeply planted peach roots.

Tests at the Davis Station show that French prune will not grow readily by stem cuttings, and but poorly by root cuttings or by layerage. A fair degree of success has been had in bench-grafting short pieces of French prune roots to French prune scions.

Marianna plum as a rootstock for stone fruits. The Marianna was introduced into California about 60 years ago and was tried to a limited extent as a rootstock for plums and apricots. It was propagated entirely by stem cuttings, and distributed principally in Placer County and at Vacaville, Solano County. About 30 years ago, at least one nursery grew it by cuttings quite extensively for a few years and distributed many French prune trees on it, mostly in Sutter, Yuba, and Butte counties. Renewed interest has been shown in this stock in the past 10–15 years, especially with several vigorous seedling selections made by this Station. Many thousands of plum and prune trees have been planted recently on these stocks

by growers throughout central California. A small number of apricot and almond trees have been planted on them in wet situations. Identifying numbers (2623, 2624, etc.) have been given to the vigorous selections to distinguish them from the original or "parent" variety.

The parent variety has been tried for plums in the United States and other countries. Reports on its performance are varied—from satisfactory to definitely unsatisfactory for some plum varieties. Most plum and prune varieties observed on it in California have performed satisfactorily. At Davis Blenheim, Tilton, and Newcastle apricots were performing well at 15 years of age, with smooth, normal graft unions. This root was used for apricots in unirrigated orchards at Vacaville some 50 to 60 years ago and they were believed more drought-resistant than those on myrobalan. Numerous nursery and orchard tests show that it is not a suitable stock for peach vareties. Most of the common almond varieties are more adaptable to it than they are to myrobalan.

The Marianna plum originated in Texas and is generally supposed to be an open-pollinated cross between myrobalan and one of the native plums of that area. Just below is a photograph (fig. 11) showing the leaf and fruit characteristics. The ovoid fruit is about 1¼ inches long, yellow-skinned, with a pale to bright red blush overspread with thin bloom when ripe, with clinging stone of much larger size than that of a typical myrobalan. Trees are large and very vigorous, with a broad, spreading top. The leaves are not recurved like most of the myrobalans, though some strains of the latter have thin, flat leaves like that of the Marianna. The branchlets are slender, at first greenish, changing to a dull reddish-brown.

The fruit is more pointed than that of the myrobalans, and the flavor and flesh resemble that of the Improved Wild Goose, *P. munsoniana*—suggesting relationship to that species. However, there are myrobalan strains which have considerable resemblance to Marianna. In its leaf characteristics and almost spineless

Fig. 11. Branch of Marianna plum. Fruits are larger and more oblong and leaves more flat than those of the typical myrobalan plum.

branches it resembles some of the vigorous myrobalan selections, such as the Myrobalan 29 group. *Prunus bokhariensis* from India (S.P.I.40229) has both leaves and fruits very similar to it. These facts might well give rise to some doubt as to its relationship with the American Wild plums. Apparently no genetic work has been done with the Marianna to try to determine its true relationships.

Some of the vigorous seedling selections have fruits very similar to the parent Marianna, while others such as Selections 2623 and 2624 have distinctly different fruits.

Old-time growers reported the Marianna was abandoned as a rootstock because suckers sprang up around the trees worse than with other plum roots, and because it was considered shallow-rooted. However, the suckering is not often a serious nuisance, being mostly out between the rows rather than from the root crown, indicating that it has some shallow roots. In very shallow soil or where a high water table has kept the roots near the surface, troublesome suckering has followed deep cultivation. Subsoiling or changing to very deep cultivation has been observed to cause suckering both with the parent Marianna and the vigorous selections. In addition, the suckering was more profuse than with common myrobalan-seedling roots. Observation of a number of mature trees on this root which have been pulled up indicated that they had a greater number of their large roots near the surface than is usual with the myrobalan (See pages 17 and 18). They also had a system of deep roots comparable to the latter variety as shown in fig. 12, top of page. The roots were studded with fine, hairlike laterals similar to those of the myrobalan and made an extensive system of fibrous roots near the surface.

Some growers object to nursery trees of Marianna produced vegetatively on account of the roots all arising from the lower end of the cuttings and spreading out horizontally—commonly called "duck-footed" trees. They naturally infer that duck-footed nursery trees would make shallow-rooted orchard trees. However, during a heavy wind storm in February, 1938, French prune trees on this root in Sutter County were not blown down so freely as those in neighboring orchards on myrobalan-seedling roots. In one of our test plots in Yuba County a few French prune trees on myrobalan root blew over, but none of those on Marianna were disturbed. These trees were 7 years of age.

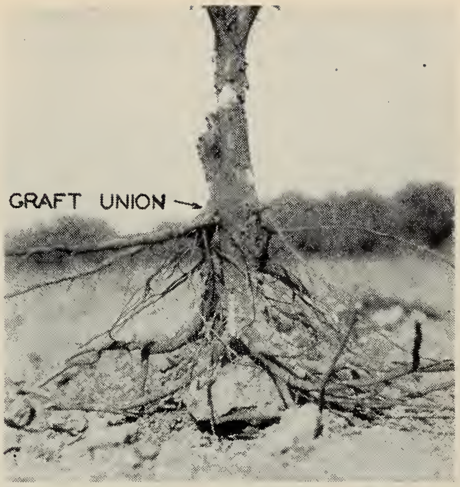

Fig. 12. Five-year-old apricot on Marianna root, showing system of surface roots of Marianna which developed just below the graft union after the tree was planted.

It is probable that for some purposes this stock or at least its vigorous selections will prove equal or even superior to myrobalan seedlings. Their complete immunity to the root-knot nematode has made them highly acceptable in certain very sandy soils in the interior valleys. Santa Rosa, Beauty, Duarte, and President plums are growing creditably on Marianna 2623 in this area. They seem distinctly tolerant of hot sandy soils. The partial resistance to oak fungus of Selection 2624 may prove of value in areas affected by this disease.

The parent Marianna is a more vigorous grower than the usual myrobalan seedlings. It and its more vigorous selections should therefore make a good replant in old orchards for later topworking. The parent Marianna is reported to have been used for this purpose many years ago in unirrigated orchards in the Vacaville district, where it is said to have been both more drought-resistant and more tolerant of wet feet than myrobalan. The vigorous selections seem especially suitable as replants. Observations indicate this stock is as resistant to excess soil moisture and flooding as is myrobalan, possibly more so; but further checking is necessary, especially in regard to the vigorous seedling selections.

Several plum orchards on the parent Marianna root have been located in Placer County, ranging from 15 to 40 years of age. The following varieties appear to do well on it: California Blue, Grand Duke, Hungarian, President, Beauty, Burbank, Duarte, Kelsey, Santa Rosa, and Wickson. Grand Duke, Santa Rosa, Burbank, and Wickson trees were about 40 years old and performing well. Trees on this root are reported to suffer less when irrigation was withheld than did those on peach root in adjacent parts of the orchard. On the parent Marianna, Giant and Pond grow dwarfishly, and Gaviota is slow-growing but is finally making good trees. Growers believe President is doing much better than on myrobalan. Observation of hundreds of replants of Marianna grown for later topworking to plums shows that this variety is seldom affected with bacterial gummosis, even in plum orchards where this disease was particularly severe. However, when these trees were top-worked to Santa Rosa and other susceptible plums and prunes, the disease was often severe on the plum varieties. The vigorous Selection 2624 is more susceptible than the parent stock.

At Davis trees have been grown up to 12 years of age on roots of the parent Marianna. The trees of Santa Rosa, Wickson, and Satsuma were doing very well; Diamond and Clyman were rather small; and Giant was distinctly dwarfed. In Sutter County there are a number of French and Imperial prune orchards about 25 to 30 years old on this stock. Wherever comparisons could be made the trees were doing as well as those on myrobalan root. In fact, they usually bore more heavily and the fruits were larger. However, in one of the older of these orchards the trees on Marianna were declining in vigor much more rapidly, and those on myrobalan had become the largest trees. This behavior appeared very similar to that of peach-rooted prune trees in this district, which bear heavily and decline in vigor earlier than do those on myrobalan. As with prunes on peach roots the decline and die-back condition was perhaps due to overbearing on a soil deficient in available potash.

In the past 10 to 15 years we have planted French and Robe de Sergeant prunes, President and several other plums, apricots, and almonds on the vigorous Marianna selections; a number of orchards have been set out to these and other varieties. Robe de Sergeant prune, and Kelsey and President plums have not always performed well on peach, apricot, and myrobalan-seedling roots. They are doing much better on the vigorous Marianna selections, and it appears likely that these are solving the rootstock problems of these varieties. Myrobalan 29 is also promising in this regard.

The following species of American wild plums (15-year-old trees) on the parent Marianna have grown normally at the Davis Station: *Prunus hortulana*, *P. orthosepala*, *P. alleghaniensis*, and *P. mexicana*. The Marianna root crown was enlarging in diameter more rapidly than the trunks of the scions. *P. mexicana* and *P. alleghaniensis* made rough or warty unions while *P. hortulana* and *P. orthosepala* made smooth unions. Two trees of the Japanese apricot (*P. Mume*) on the

parent Marianna root at the Davis Station have not grown well, and at 14 years of age were very dwarfish and unhealthy in appearance.

Seedlings grown from seed of the parent Marianna vary considerably in vigor in the nursery—some being quite dwarfish while others are unusually vigorous. Growers trying this root should use only vegetatively grown stock.

All the Marianna seedling selections retain the resistance of the parent variety to the root-knot nematode. The three most promising have the numbers 2624, 2623, and 4001. Of the three, 4001 is most vigorous, 2624 least. This rating does not indicate that varieties grown on them would necessarily grow in vigor in the same order, nor even more vigorously than on any other rootstock.

The following plums have been observed to be growing well in orchards on Marianna Selections 2624 and 2623: Santa Rosa, Beauty, Duarte, President, and French, and Robe de Sergeant prunes. In one orchard at least Hungarian and Emilie plums are not growing well on Selection 2624, but there may be some soil condition there causing their poor growth. French prunes 16 years old on Selections 2624 and 2623 are performing better than those on peach root in a test plot near Vacaville. A test plot of French prune on these stocks in comparison with the parent Marianna, myrobalan, peach, apricot, and almond roots at Davis is too young (10 years) to make definite comparisons. Santa Rosa, Beauty, and President are growing very well in nematode-infested sandy soils of the San Joaquin Valley. Apricot varieties do well upon them, though it is too early to make definite recommendations regarding the preferable selections for this fruit.

Peach and almond on these selections are discussed in later sections dealing with these fruits on plum roots. Also for a detailed discussion of these stocks in relation to diseases see sections on oak-root fungus and nematodes (pp. 8–9).

Fig. 13. Apricot tree, about 28 years, on myrobalan root. Broken smoothly at the union when the tree was pulled by tractor. The large root turned upward at the right is an apricot root which had grown above the union, the tree having been planted with the union below ground.

Apricot varieties on plum roots. Like the prunes, apricots have been grown in California on all four stocks and afford valuable studies in rootstock behavior. Many successful apricot orchards are on myrobalan root, which was usually selected because of its resistance to excessive soil moisture. While apricot on myrobalan root will endure quite heavy soil, it does not bear so well as it does on lighter soils, at least in some districts. Apricot is not so satisfactory on myrobalan as on apricot and peach roots, provided the soil is not too wet for these two latter stocks. It does not make an entirely satisfactory union, and occasionally a few trees in an orchard break off at the union during wind storms. The percentage of trees lost in this way is very small and is a relatively unimportant factor in the success of the orchard as a whole. Myrobalan-rooted apricot trees with poor unions sometimes fail to grow rapidly and finally become stunted, though at other times such individuals grow well for some years and then become chlorotic and may linger for some years before dying.

When apricot trees are pulled up with

a stump puller or a tractor, quite a large percentage of those on myrobalan root often break off more or less smoothly at the graft union (fig. 13).

Nurserymen complain that in the nursery too many apricot trees on myrobalan seedlings either fail to grow rapidly, or do not grow sufficiently upright, or else have weak or rough unions. By the time the grower gets them they have been pretty carefully culled out to meet inspection requirements. Otherwise there might be more trouble than there is with this combination in the orchard.

The crown of the myrobalan root usually grows much larger in diameter than the apricot trunk, giving what is commonly called a "churn" bottom. At other times the union is merely enlarged and rough. Contrasted to this, in the case of apricot root, the union is almost inconspicuous, whereas with peach root the crown may be considerably swollen although the union is usually smooth.

Fig. 14. Four-year-old inarches of apricot seedlings into apricot trunks. Seedlings were planted beside an ailing mature Blenheim apricot tree that was on myrobalan root; tops of seedlings were "inarch"-grafted into the Blenheim trunks. Trees showed marked recovery after 3½ years' growth.

Observations indicate that soil conditions sometimes affect the success of the union between apricot and myrobalan. In several orchards most breakage was on areas of heavier soils; in others there was less wind breakage on the poor soil where the trees grew less vigorously. A few cases of pinch root (fig. 8) of apricot on myrobalan root have also been observed. In several counties, apricot on myrobalan has come into bearing at an earlier age than on apricot and peach roots.

Many orchards in Hollister Valley, San Benito County, are on myrobalan root. This root was usually chosen because of heavy soil, the growers fearing it would be too wet for apricot root. Since the soil in most of these orchards has not proved too wet for apricot root, this would no doubt have been the better choice. Most orchards on this root are doing well, though as noted below there has been some leaf scorch and die-back and much more damage by peach-root borer than with trees on apricot root.

East of Hollister, San Benito County, are many apricot orchards on a shallow, loamy soil with a compact clay subsoil beginning at a depth of 18 to 24 inches and extending downward for about 4 feet, below which are sedimentary deposits. This soil is mapped by Cosby and Watson (1923) as Rincon loam. Here apricot roots penetrate the clay more freely than do those of myrobalan—the latter tending more than the apricot roots to spread out horizontally above the clay. Except in some areas which become too wet in years of prolonged rainfall, the trees on apricot root do better than those on myrobalan in this soil; apparently apricot roots secure moisture more readily from the clay subsoil than do the myrobalan.

In some irrigated orchards on this type of soil the trees on apricot produce larger fruits than those on myrobalan root. Also in the deep soils of the Hollister Valley there has in recent years appeared a

decadence of apricot trees on myrobalan root accompanied by more or less leaf scorch and cupping of the leaves. With a few exceptions the trouble is with trees on myrobalan root. Proebsting and Hansen (1943) have shown that this difficulty is confined to myrobalan. They have improved the condition of declining trees by planting apricot seedlings beside them and grafting (inarching) their tops into the trunks (fig. 14). They have discovered deeply planted trees that have grown apricot roots above the bud union, and these are free from leaf-scorch symptoms. Lilleland (1945) has found evidence that the difficulty in some of the cases is excess alkali in the soil—trees on myrobalan showing more "scorch" than those on apricot root.

Growers in the Hollister Valley have reported that with myrobalan root brown and green rot of the apricot blossoms and fruit are more severe, and in general the bearing is more erratic than on apricot root. They state that with myrobalan root the blossoms often appear earlier and the jacket (calyx) sticks on the young fruits longer than with trees on apricot root favoring infection by these diseases.

The same phenomena have appeared in Suisun Valley in a comparison of trees on myrobalan and peach roots. With Blenheim and Royal on myrobalan roots the ripening fruits split worse at the blossom ends — apparently admitting more freely the spores of brown-rot fungus. One fresh fruit shipper reported that fruit from myrobalan-rooted trees is more subject to this rot in transit than from trees on apricot and peach roots. An orchard owner reports that the fruits of Tilton apricot on myrobalan ripen a day or two earlier than on apricot and peach roots.

At Brentwood on a clay loam there seems no difference in size or quality of fruit of Tilton trees on the three stocks. In one orchard there was a heavier set of fruit on myrobalan, requiring more expense in thinning. Trees on myrobalan root are more deeply rooted in the heavy soils than are those on peach.

Apricot trees on myrobalan, as mentioned elsewhere, are much more subject to bacterial gummosis than on apricot and peach roots.

At Davis there were recently pulled out two trees each of Blenheim apricot six years old, on the following plum roots grown from cuttings: Marianna seedling Selections 2616 and 2620, myrobalan seedling Selections 2–7, and 3J, Black Damas C and D, St. Julien B, E, and G, Common Mussel, Brompton, Blaisden Red, Etters Giant (*Prunus subcordata* × *P. domestica*), Home (*P. salicina* × a hybrid) and Sapa (*P. Besseyi* × *P. salicina*). The most promising of these, judging from vigor of tree and depth and spread of root system were the myrobalans and Mariannas, though Black Damas C, St. Julien B, and Brompton were close competitors.

Peach and nectarine varieties on plum roots. Though many plums do well on peach root, or top-worked upon peach varieties, yet the reverse combination—peach varieties on plum roots—are not as a rule very successful. The peach is partially satisfactory on roots of certain strains of St. Julien and Damson plums, and this graft combination has been quite freely used in England and Europe. Though dwarfed there on these roots, they are only slightly undersize in California.

Myrobalan root has occasionally been tried to adapt peaches to wet soils. Generally they prove short-lived. In 1925 and 1926 the late Dr. W. L. Howard planted two trees each of 25 varieties of peaches on myrobalan seedlings and 5 varieties on rooted cuttings of the parent Marianna; in 1927 six varieties on *Prunus angustifolia;* and in 1928 nine varieties on St. Julien seedlings, the seeds of which were from Italy. Not many of the 25 varieties on myrobalan root have prospered. A few of these died within a year or two. Some dwarfish ones lingered

Fig. 15. Root system of 16-year-old Lovell peach tree on myrobalan root. This tree grew slowly the first few years, then produced peach roots above the graft union, and thereafter progressed more rapidly. When pulled up it was found that the peach roots were dominating the whole root system and that the only myrobalan roots remaining were a few small ones (marked with pieces of cloth). It was almost as large as a nearby Lovell tree (same age) on peach root.

for 8 or 10 years, when the weakest were pulled out. One tree each of Paloro, Phillips Cling, and Late Crawford and two of Peak, Tuscan, Hauss, and Orange Cling have grown almost normally. However, all but Hauss, Peak, and one Tuscan had developed strong scion roots above the union, and these peach roots were dominating the myrobalan roots.

Elberta, Lovell, and Susquehanna were distinctly dwarfed, but one of each, growing better than its companions and more vigorous in later years, was found to have a complete peach root system outgrowing the myrobalan, as shown in the case of the Lovell variety (fig. 15).

The following varieties were short-lived, and mostly very dwarfish: Salwey, Early Crawford, Late Crawford, Briggs Red May, Elberta, Lovell, Levy, Strawberry Cling, Alexander, Mayflower, Foster, Muir, Susquehanna, Lemon Cling, St. John, Leona, Ontario Cling, Libbee Cling, and Lovell. Of these the following (one or both trees) were partially sustained by scion roots: Elberta, Sims Cling, Late Crawford, Susquehanna, Lovell, Ontario Cling, Libbee Cling.

The lack of congeniality between peach and the myrobalan root was indicated in our nursery where many peach scions, after making a growth of $3\frac{1}{2}$ to 6 feet on myrobalan root became chlorotic in midsummer and died (fig. 16). An interesting case is that of 12 Hauss Cling trees on myrobalan, four of which died in the nursery. Five of the best of the remaining ones were transplanted to the orchard the following winter, and four of these grew normally. After three years two of the

Fig. 16. Hauss cling peach on myrobalan root. After making 3 to 4 feet of growth in the nursery many became chlorotic, wilted, and died. This behavior is usual with peach varieties budded on most kinds of plum roots. Planted in the orchard, a small percentage may live (most of them dwarfishly) for some years, but very few grow normally.

best were selected for permanent trees (fig. 17). These were as large at 16 years as similar ones on peach root, and bore heavily, with fruits of equivalent size. On page 42 is a photograph (fig. 18) of the graft union of one of these trees. They were pulled by tractor when 23 years old. These two trees did not develop scion roots.

Presuming that the particular myrobalan seedlings on which these Hauss peaches were growing would make congenial rootstocks for this variety, cuttings from the roots of one were made and planted in the nursery under the selection number 9Ib. They were then budded with buds from the same Hauss tree from which the roots had been taken. Contrary to expectations, most of the Hauss tops, after growing vigorously for some four months in the nursery, began to turn yellow and soon died. A few which survived were planted in the orchard, grew for one to two years, then became chlorotic and died.

Death of peach on myrobalan-seedling roots in the nursery usually started at the tips of the roots and progressed upward until the entire vascular system of the central axis of the underground part was involved. Some trees which survive develop characteristic bark colorations—usually yellowish or a pale pink. The wood and bark union between peach and myrobalan is usually strong and apparently normal so that the incompatibility is perhaps physiological rather than structural. In some cases of delayed incompatibility, the bark union finally failed to grow normally. The behavior of some peaches on certain plum understocks indicates that possibly a virus disease, perhaps latent in either the scion or the understock, was the cause of the failure rather than a physiological incompatibility.

Fig. 17. Hauss Cling peach on myrobalan seedling roots. Planted in the spring of 1925, photographed in the fourth season's growth. This tree and one next to it have grown normally for 23 years, while companion trees of the same combination failed to make good trees. They have not grown scion roots above the graft union. The next picture shows the slightly enlarged graft union of this tree when 16 years of age.

Peach on Marianna. Peach varieties on Marianna in the nursery behaved similarly to those on myrobalan; that is, quite a number after making vigorous growth died or became chlorotic in the late summer and fall. This occurred in the case of all 27 varieties tried one year in the nursery.* Salwey seemed the most congenial of any to Marianna and myrobalan roots. Most of those that were chlorotic, and a few of normal behavior, died when later transplanted to the orchard; in most cases only the scion died. Of those planted on Marianna in 1926, four Paloro and one each of Muir and Tuscan were thriving when pulled in 1945, though the Mayflower, Phillips Cling, and Orange Cling either died the first year or lingered a year or two. In most of these latter cases the tops died

* Peach on *Prunus Besseyi* seedlings performed in the same manner.

Fig. 18. Hauss Cling peach 16 years old on myrobalan root. The union had become covered to about 6 inches below ground. The overgrowth of the peach trunk is not so great as usually occurs with peach on this root.

and the roots survived. The peach trees that survived were only slightly undersized, considering the close planting (12 × 12). The peach considerably overgrew the Marianna rootstock; in the case of Tuscan and one Paloro, scion roots from above the graft unions partially supported the trees.

Peach on St. Julien and Damson plum roots. Two trees each of the following varieties were planted on St. Julien seedling roots in the Davis orchard in 1928: Muir, Sims, Tuscan, Ontario, Hauss, Red Bird, White Heath, Late Crawford, and Elberta. Most of them have grown well though not as large as similar trees planted nearby at the same time on peach roots. Red Bird and one each of the following grew poorly: Tuscan, White Heath, Elberta (4 planted). Some had small peach roots above the graft union; hence comparative measurements in later years could not be made. On page 42 is shown one of the Elberta

Fig. 19. Elberta peach on St. Julien seedling root, 22 years of age—about ¾ normal size: height 18 feet, spread 24 feet, trunk diameter 13 inches.

trees (fig. 19), which had not grown scion roots at 22 years of age. It is 18 feet high and 24 feet across, and the trunk diameter at the smallest point is 13 inches. It has borne well and has fruit of very good size and flavor.

The peach overgrows the St. Julien root to a considerable extent. In some cases St. Julien roots have produced sprouts out in the rows between the trees. Most of the above trees developed a few small scion roots by the eleventh year, but only in the case of Hauss and one each of Sims Cling and Muir did these become large enough to help sustain the tree.

In England's cool climate peach fruits will not ripen well except in greenhouses or where trees are trained up fanshaped against a warm wall in the open. These are grown principally on St. Julien root, and by repressive pruning are kept in a semi-dwarfed condition. Dr. W. L. Howard observed trees of this kind on St. Julien roots doing well in England at 30 years of age. In France seedlings of both St. Julien and the similar Damas (Damson) plums are commonly used as a rootstock for peaches. They are said to be especially well suited to some of the eroded and "worn out" soils. Lake (1901) reported that French horticulturists find St. Julien and other plum stocks preferred for peach because they are deeper feeders, live longer, and are less susceptible to adverse soil conditions.

Considerable interest exists in northern California regarding the possibility of peaches on plum in flooded and low areas where trees have been killed in recent wet winters. Eight years ago a trial orchard was planted at Davis, in which 16 varieties of St. Julien and Damson plums were used as rootstocks for peaches. These varieties and others were also tried as intermediate stocks between plum (myrobalan, etc.) roots and peach tops. These peach trees are still too young to provide positive conclusions as to which varieties produce the best seedling roots, or which the best intermediate stocks. The seeds of one or two varieties already indicate promise, and several look good as intermediate stocks. Other promising intermediate stocks for some peach varieties are Blenheim apricot, French prune, and Santa Rosa plum. The usefulness of an intermediate stock would be to provide a ready method for nurserymen to propagate peach trees on plum roots, when the proper kind of seeds or seedlings were not immediately at hand.

Peaches on other plum rootstocks. Argles (1937) states that in the experiments at the East Malling Station in England the Brompton plum grown vegetatively has been the best of the plum rootstocks tried for peaches. Tests at the Davis Station indicate that Brompton would not be successful, as an intermediate stock, for many of our varieties.

In the Davis Station nursery Elberta and Mayflower were distinctly below normal in vigor on seedlings of *Prunus hortulana.* Hutchins (1936), working in Georgia, reports that peach on the native Hortulana plum, *P. hortulana,* is very dwarfish, though resistant to the root-knot nematode. Johnston (1938) reports peaches to be unsatisfactory on *P. mexicana* and *P. hortulana* in Michigan. The following varieties were planted in the orchard at Davis on Chickasaw plum (*P. angustifolia*): Tuscan, Paloro, Ontario, Early Crawford, Alexander, and Phillips Cling. These were considerably dwarfed and the scion greatly overgrew the rootstock—forming a large bulge immediately above the union, at the time the test was discontinued when the trees were 20 years old.

Almond varieties on plum roots. Though many plum and prune varieties do well on almond root, or when topworked upon almond varieties, yet the reverse combination of almonds on plum roots has not been entirely satisfactory commercially. In home gardens and in small areas in orchards, myrobalan plum roots have been more or less successfully

used to adapt this fruit to soils too heavy or wet for almond and peach roots. Experiments are in progress at Davis to find a satisfactory plum root on which to grow almond varieties in such situations.

In 1925 and 1926 in an orchard at Davis the late Dr. W. L. Howard planted a few trees of Drake, Languedoc, I.X.L., Ne Plus Ultra, Nonpareil, and Texas almonds on myrobalan-seedling roots. They have been only partially successful—some of each variety doing poorly while some were performing fairly well when taken out at 22 years of age (fig. 20). Even with those that grew satisfactorily, the almond overgrew the myrobalan considerably, and usually there was a slight bulge immediately above the union. Those not doing well were usually "carrot-rooted" (page 30), whereas the root crowns of the trees that did grow normally were nearly as large as the almond trunks. In all cases the unions were strong, there being no tendency toward breakage in windstorms or when they were finally pulled up by a tractor hitched to the trunk. In several orchards much greater overgrowth of the almond above the union with myrobalan has occasionally been seen.

Fig. 20. Texas almond on myrobalan root, 14 years, in experimental orchards at Davis.

In the Station nursery the affinity of almond with myrobalan root varies from seedling to seedling. Some die in the nursery after growing well till midsummer, or become chlorotic and remain sickly throughout the rest of the summer. After the best of the survivors are planted in the orchard, a considerable percentage either die the first season or fail to grow thriftily. This behavior is very similar to that described for peach on myrobalan roots (p. 45). The varieties Nonpareil and Drake are the most difficult ones to grow on plum roots.

Several mature orchards have been observed on myrobalan and Marianna roots; and one (on the parent Marianna) under observation for several years was about 45 years of age. In general the trees were not so large as those on almond and peach roots, and quite a percentage were doing poorly. Though no yield records are available, under good soil and cultural conditions production is lighter on myrobalan than on almond roots. Nonpareil and Drake seem the most difficult to grow on plum roots, but a few trees of these varieties up to 35 years old have been observed, which seem to vary in vigor from seedling to seedling.

Some attention has been given to the use of intermediate stocks between almond varieties and plum roots. Nonpareil and Drake require some such method if they are to be grown successfully on plum roots. Some progress has been made with this method. It is likely that the other common varieties will be satisfactory worked directly onto either one of the two Marianna Selections 2623 and 2624, propagated by cuttings. None of the almond varieties is apparently compatible with the very vigorous Marianna Selection 4001. The parent Marianna likewise does not seem sufficiently congenial with some of the almond varieties. Out of a number of intermediate stocks for Nonpareil and

Drake one of the St. Julien selections has given the most promise, after 6 years' trial. Varieties also appearing to grow well upon this selection as an intermediate stock are: I.X.L., Jordanolo, Ne Plus, Peerless, and Texas.

The following varieties seem fairly satisfactory with French prune as the intermediate stock: I.X.L., Jordanolo, Ne Plus, Peerless, and Texas. These varieties (except Jordanolo) have been growing for 21 years on French prune (on myrobalan root) at Davis. Beginning in the third year after top-working onto 10-year-old prunes, they have borne heavily, with crops of good fruits. Though still apparently healthy, they are not particularly vigorous as measured by new tip growth. A few trees of this combination, said to be about 35 years old, were observed in Capay Valley, Yolo County.

Jordanolo has been particularly successful on various plum roots and intermediate stocks, as evidenced by the following list of understocks on which it is growing well at Davis: Myrobalan 91b,[12] St. Julien (Havens 2b, St. Julien 11M, French prune, Marianna 2623 and 2624. It does not do well on Marianna 4001. None of them has done well on the Myrobalan 29 selections, nor on Myrobalan 3J.

A more extensive test is now under way with the plums which the above preliminary experiments and observations indicated are most promising as intermediate stocks.

In the nursery the more common almond varieties have been budded onto a number of selections of myrobalan, St. Julien, Damson, and Marianna. The most promising appear to be Marianna Selections 2624 and 2623. Planted in the orchard, all except Nonpareil and Drake have grown well for 7 years on Marianna Selection 2624. In another trial Peerless on Marianna 2623 has grown well for 12 years. One of the latter was top-worked, when 2 years old, to Nonpareil. It grew rather poorly the first two years, but since then the Nonpareil appears normal in growth and productivity. They did not do so well on the parent Marianna, and none of them prospered on Marianna Selection 4001. The latter is the most vigorous plum stock that has been found at the Davis Station. Several intermediate stocks are being tried between Marianna 4001 and Nonpareil. Experiments in the use of almond varieties on Marianna 2624 for possible resistance to oak root-rot fungus are discussed on page 10. To insure rapid development, young almond trees on plum root should not be pruned heavily nor allowed to overbear the first few years.

[12] See page 41.

VIII. PEACH ROOTS FOR STONE FRUITS

Seedlings of the common peach, *Prunus persica* Linn., have been used satisfactorily as rootstocks for all of the peach, nectarine, and apricot varieties, and for practically all the Japanese and most of the European plums and prunes. Under some conditions they have not proved successful for almonds, though possibly over half the almond orchards in the state are on this root. Ways of distinguishing the roots of peach from other stone fruits are discussed on page 6.

Unlike the myrobalan and other plum roots, peach is not tolerant of wet soils. This root grows best on light soils but will endure moderately heavy soil providing the surface drainage or downward percolation of water is sufficient to prevent prolonged water-logging of the soil. Our most productive orchards of peach and other stone fruits on peach roots are not generally found on the heavier soils.

In non-irrigated situations plum and prune trees on peach root suffer from drought worse than those on almond and myrobalan roots, but not so much as those on apricot root. In irrigated orchards if irrigation is withheld from trees for too long a period those on peach root

show distress more readily than do those on myrobalan root.

It is sometimes stated that peach root is short-lived, this being perhaps inferred from the fact that peach orchards themselves are short-lived. However, regardless of kind of root, when the top is a long-lived variety (such, for example, as French prune or apricot) the orchards have often attained an age of 70 to 80 years, or more. Again, peach trees with decadent non-productive tops frequently send up peach suckers from the roots, and these live for many years longer than the original scion variety.

Peach wood, both tops and roots, is very subject to internal wood-rotting fungi, and these organisms often hasten the decline of both tops and roots. Rots often get into the peach roots by way of injuries made by the crown-gall disease and by root borers. A temporary high-water table has been observed to injure the deeper roots and thus initiate wood rots, which later work up into the heart wood of the trunk and scaffold branches.

On soils with excess lime or underlaid with marly layers, too close to the surface, stone fruit varieties on peach root are quite subject to lime-induced chlorosis. Peach root is sensitive to excess alkali in the soil and irrigation water (discussed on page 22).

In the wet spring of 1938 when nursery trees could not be transplanted to the orchard before late April and May, many peach trees (on peach root) were placed in cold storage to hold them dormant until the soil was in proper condition. In Yuba and Sutter counties trees thus handled did not usually grow well if transplanted after about May 15. A few cases were noted where with good care favorable results ensued when planted as late as June 1. Nursery trees placed in cold storage after leaf buds had started to open did not do so well as those stored earlier.

Source of peach seedling nursery stock. California nurserymen are using mostly seeds of the Lovell freestone peach secured from dry yards and canneries. The seedlings are more vigorous than the Muir and Elberta, the only other freestones used for drying whose seeds are available in large quantity. The early vigorous growth of Lovell seedlings is particularly useful for June budding stocks. In the past 8 or 10 years (as discussed later) there have also been a large number of trees budded to certain peach seedlings which are resistant to the root-knot nematode, for planting in sandy soils where this pest is present.

While the percentage of germination of Lovell seeds is not always high, yet it is higher than that of Muir and Elberta. Elberta does not make such satisfactory trees to work in the nursery as does Lovell and Muir. Salwey was at one time largely used, but the acreage of this drying freestone has so diminished that sufficient seeds have not been available for 30 years or more. There is no evidence that it was in any way superior to Lovell.

California nurserymen formerly used Carolina or Tennessee "naturals" imported from eastern seedsmen. The Silva-Bergtholdt Nurseries at Newcastle, Placer County, had a few trees of these to supply at least a part of their seed. These southern "naturals" were not of sufficient merit to warrant their continued use. One nurseryman states that years ago he tried seeds from southern "naturals" growing in Tehama County, and that they did not appear to make better seedlings than those from Lovell seeds.

Suckers of seedlings from these "naturals" have been observed in old orchards in California, and a few were selected for growing at Davis. As described by Gardner and Marth (1937), "This peach is a small white-fleshed freestone and the great uniformity of its seedlings (in the nursery) suggests that it is genetically quite homozygous. When more peaches of its character were desired by farmers, it was a simple matter to plant a few seeds in the yard or in some out-of-the-way

corner of the farm." Today there are not enough of these trees to supply the seed trade, and large seeds from commercial orchard varieties are sometimes mixed with the small naturals. California quarantine laws have long since prohibited the importation of peach seeds and seedlings from Carolina and Tennessee because of the presence there of peach yellows, peach rosette, and the phony disease. Lovell seeds are shipped in large quantities from California to eastern nurseries.

On page 48 is a photograph (fig. 21) showing the relative vigor of one-year-old seedlings of Lovell, Salwey, Elberta, and Muir as they normally grow in the nursery at Davis. Nurserymen report this same order of vigor. To test the possibility that this relative vigor might affect the growth and productivity of peach trees in the orchards, Phillips Cling peach was budded to all four stocks, and the resulting trees were planted in a San Joaquin County orchard in 1928. At 10 years there were no differences in size or productiveness. Also at Davis in 1928 on these four peach seedling stocks the following were planted: J. H. Hale and Muir peach, Yakimene and Royal apricot, Grand Duke and Wickson plums, and Nonpareil and Ne Plus Ultra almonds. At the end of three years the trees of each variety group were found to be of approximately the same circumference regardless of the rootstock. The details of this test were published by Day (1937). We must of course take into account that other varieties might possibly have shown either preferences or antipathies to one or more of these four stocks, with results differing from these.

In 1926, 1927, and 1928 at Davis a number of varieties of plums, peaches, and apricots were planted on seedlings of Muir and the Strawberry Free peach. The latter makes very vigorous nursery seedlings. Yet after 10 years there were no noticeable differences in size of the varieties on the two stocks.

The seeds of approximately 350 varieties of peach and nectarine have been planted in the nurseries at Davis. Comparison of these showed that some 25 varieties made promising rootstocks, but possibly none was enough superior to the ones commonly used by nurserymen to warrant a change from these long-tried varieties, the seeds of which are readily procured. There was a considerable diversity in character of the root systems, some spreading and others with tap roots, etc. Among the more vigorous types were seedlings of Lovell, Shalil, Bokhara, Lukens Honey, and three varieties from Yunnan, China (S.P.I. 55885, 55886, and 55888). In nurseries in loam soils, Bokhara seedlings usually have two or three roots which grow directly downward, side by side, often making it difficult to secure a well-balanced root system for transplanting to the orchard. However, these trees when transplanted make excellent growth. In nurseries in sandy soils Bokhara seedlings have a more spreading root system.

Seeds of several strains of the peach-almond (hybrid between peach and almond), including a vigorous strain known as Mexican Peach-almond, have been tested at Davis. The seedlings of these did not seem to have any points of superiority over ordinary peach and almond seedlings. Seed germination was very poor, and the seedlings lacked uniformity in vigor, some being quite small while others were unusually vigorous growers. Crown-gall infection was perhaps a little more common than on peach seedlings, and at least one nurseryman reports that peach-almond seedlings are much more subject to crown gall in the few strains he had tried, being comparable in this respect to almond seedlings.

The writer is testing for seed purposes several very vigorous peach-almond seedlings which appeared among almond seedlings in the nematode-resistance test nursery at Delhi. Apparently these are natural or open-pollinated crosses be-

Fig. 21. This picture shows differences in growth of one-year-old peach seedlings; left to right: Lovell, Salway, Elberta, Muir. Seedlings were budded to a number of varieties of peach, almond, apricot, and plum. The resulting trees were planted in the orchards; within 2 to 3 years no differences in size of trees on the different rootstocks could be noted, nor had any appeared at 10 years of age.

tween almond and peach. They were free from nematodes although growing next to almond seedlings severely affected by that pest. When transplanted to an infested orchard even the most vigorous one discovered was freely attacked by nematodes, but it grew very vigorously in spite of a heavy infestation of nematodes and a large crown gall.

Davis (1928) reports that in South Africa prunes on a strain of peach-almond roots have been known to survive and continue to bear good crops of fruit after other trees in the same orchard, worked on other roots, have died from the effects of alkali in the soil. Peach is also sometimes used there on peach-almond root on alkali soils. The fruit is said to ripen earlier than on peach root.

In the earlier days in California when freestone nectarines were commonly dried and canned, nurserymen report that the seeds were sometimes used as sources of seedling rootstocks for plums and peaches. They were said to perform as satisfactorily as peach seedlings.

Vegetative propagation of peach rootstocks. A number of peach varieties (including Shalil and Bokhara) were tested at Davis for rooting by layerage, with little practical success. Very few sprouts formed roots, even when kept mounded for two years. In the orchards many peach varieties on plum roots have been observed to form strong scion roots above the graft union, when the latter was planted several inches below the soil surface.

Nematode-resistant peach seedlings. Two species of nematodes injurious to the roots of fruit trees have become established in California—the root-knot nematode (page 8) and the lesion or meadow nematode (page 9). The former, thoroughly established in practically all fruit districts in the state, is injurious to fruit trees on peach root in sandy soils. Hence much interest of growers and nurserymen has centered around partially resistant or tolerant seedlings of several non-commercial peach varieties discovered by this Station, and one discovered by Stribling's Nurseries at Merced, California. It is very difficult and often impossible to grow trees to maturity on Lovell or other common peach seedlings in very sandy soils heavily infested with this pest.

The seedlings of approximately 180 peach and 45 nectarine varieties were tested in sandy soil infested with the root-knot nematode at Delhi, in Merced County. The following varieties offered some promise: Bokhara peach from Central Asia; three strains of the Shalil peach from northern India (S.P.I. 63850, 63851, and 63852); three strains of a wild peach from Yunnan Province of China (S.P.I. 55885, 55886, and 53888); Quetta nectarine; and a cross between Quetta nectarine and Bolivian Cling peach (S.P.I. 61302).

In addition to several years' tests in the nematode nursery, test plots were placed in many orchards in seven counties to test their resistance under varying soil, climate, and cultural conditions, and the possible influence of different peach varieties. Progress reports were published by Tufts and Day (1934, 1939, and 1944). Examination of the roots in the above orchard test plots revealed the following percentages of trees attacked (either moderately or heavily) by nematodes: Shalil, 19.6; Yunnan (all 3 varieties combined) 17.6; and Bokhara, 21.4. These probably do not represent either the actual or relative resistance of the seedlings of these three varieties, for many unknown factors concern the nematode in its host and soil relationships. For instance, there was no uniformity in the percentage of infested seedlings of the three kinds from plot to plot. In certain plots the percentage of infested trees would be very high, whereas in others it would be quite low. This may have been partly because of different strains or species of the root-knot nematode (page 8). In only a few instances of very sandy

Fig. 22. Texas almond, 4 years old, on Yunnan peach root. In its fourth season's growth, it was 18 feet in height and 6½ inches in trunk diameter. Although growing vigorously, this tree is also producing a satisfactory crop. It replaced a tree killed by nematodes. The stunted trees nearby are 3 years older on common almond roots.

Fig. 23. Seven-year-old Jordanolo almond on Bokhara peach roots. This tree, now 16 years old, is larger than adjacent trees on almond root.

soil was the infestation so severe as to cause retarded growth. Approximately ten per cent of the trees in these test plots were seriously retarded.

For about 13 years nurserymen have been supplying growers with peach and almond trees on the Shalil root; there are now perhaps as many as 3,000,000 trees of these in California orchards. In a number of these orchards, after making vigorous growth for some years, the trees began to decline in vigor. In some cases it is not certain that root-knot nematode is the entire cause of this decline.

Shalil is apparently more at home in sandy than in heavier soils. In one test plot on Yolo silt loam soil, Lovell grew faster on Lovell-seedling roots than it did on Shalil seedlings. Several growers believe some other varieties have not grown so rapidly as on Lovell root (where nematodes were not a factor). Hundreds of profitable orchards are on this root, 10 to 15 years old, in the San Joaquin Valley, and only a very few have failed to continue growing well.

In the experimental plots, trees on Bokhara are apparently standing the test of time in vigor better than are trees on Shalil. Most of these plantings were made where peach orchards had previously been grown; hence some may have been retarded in growth from this cause.

Bregger (1948), in experiments at the South Carolina Station, found that many varieties of peaches are not compatible with seedlings of one of the three Yunnan varieties (P.I. 35886). We did not note any incompatibilities with the peach varieties used on this stock in our tests.

Quetta is very difficult to propagate by seed as the seeds germinate poorly, most of them fermenting shortly after being stratified. Several almond varieties 10 to 15 years old on Bokhara, Shalil, and Yunnan seedlings are in the test plots. The graft unions are good, and the trees have grown well and borne normally in these nematode-infested sandy soils (figs. 22 and 23).

Stribling's Nurseries, Merced, California, have recently introduced a new nematode-resistant stock under the trade name of S37 (U. S. Plant Patent 904). This is more resistant than the above stocks and in very sandy spots has grown better than any of them. It has not been used long enough to determine whether all peach varieties will grow well on it, in the various soils used for peaches; nor whether peaches, apricots, plums, and almonds will be long-lived upon it. In the nursery it is said to be less susceptible to crown gall than Shalil. It is not immune to this disease, for several severe cases have been seen in our orchard test plots in trees on this root furnished by the above nursery.

Seedlings of Bokhara, Shalil, and Yunnan are very vigorous growers, and as interplants among old peach trees in the test orchard at Delhi they were more easily established than were budded trees on these roots. To get the best results in tree growth, in replants of these in old peach orchards, it has been found better to allow the seedlings to grow two or three years before top-working. Apparently heading back in budding and grafting operations is not so devitalizing to the tree after it has made a large root system, which can compete more successfully with the roots of older trees in the orchard. Good success in top-working by budding in July and August has been had with trees planted the previous spring, and on up to three years of age. To secure the full vigor of growth in seedlings used as interplants, they were not pruned back heavily but cut only enough to secure the desired spread. This could often be attained by cutting back to strong lateral growths, rather than "stubbing" the branches back.

Peach and nectarine varieties on peach roots. Peach and nectarine trees are grown almost entirely on peach-seedling roots in California, though under some special conditions almond and apricot seedlings have been used. These two latter are not always satisfactory and should be avoided whenever conditions permit the use of peach root. We have seen no cases indicating that any commercial peach and nectarine varieties are incompatible with Lovell peach seedlings.

Many experienced peach growers in the San Joaquin Valley prefer to plant June-budded peach trees rather than the fall-budded trees which have two-year-old roots. They believe that the one-year-old roots of June-budded trees transplant with less mortality, and that the trees have a better supply of active shoot buds along the main stems from which to select properly spaced branches. By June-budding early (April, May, and June) on seedlings produced from seeds planted only two to three months previously, nurserymen in the San Joaquin Valley are able to produce unusually large trees by the ensuing winter. These "June-buds," as they are called, are often 4 to 6 feet high; yet the roots are only one year old when transplanted to the orchard. Hansen and Eggers (1950) describe this method of June-budding orchard stock in the nursery.

Plum and prune varieties on peach roots. It is estimated that over 50 per cent of the plum and prune orchards in California are on peach root. It is a satisfactory rootstock, and nearly all varieties are compatible with it. Climax is apparently the only Japanese plum that has been reported to fail sometimes, and a few European plums and prunes are not satisfactory on it. The general trend at present is to plant plums on peach root, provided the variety is compatible with it and the soil and climatic conditions are favorable. In the interior valleys where plums and prunes tend to heavy production, prunes and some of the European plums are likely to overbear and die in the tops during the heat of summer. Reducing the crop by judicious thinning will prevent the die-back.

Beauty plum has for decades been used satisfactorily on peach root. However, in Tulare County many young trees recently died in several orchards in which Santa Rosa and Duarte have grown very well. It was at first reported that the ailing Beauty trees were all on Shalil peach seedling roots, but several nurserymen were quite certain that some were on Lovell seedlings. Beauty and other plums are growing so well on Marianna plum, and the vigorous selections of this stock, in sandy interior-valley soils infested with the root-knot nematode that there is apparently no reason to use Beauty on peach root. Since Beauty is not very subject to injury by bacterial gummosis there is no particular point in putting it on peach root where this disease is endemic, nor where root-knot nematode is a serious pest.

Among the European plums and prunes the following common varieties are for various reasons not always satisfactory on peach root: Burton, California Blue, Columbia, Diamond, Duane, Grand Duke, Green Gage, Jefferson, Robe de Sergeant, Sugar, Uncle Ben, Washington, and Yellow Egg.

In Placer County and other Sierra foothill sections, most growers prefer Grand Duke and Diamond on myrobalan; but peach root is preferred for President and California Blue, and for the Japanese plums (except Climax). Plum and prune trees on peach roots are not usually so severely injured by bacterial gummosis as are those on plum rootstocks.

Grand Duke and Burton prune overgrow the peach root, but practically all the unions are strong. Grand Duke is fairly satisfactory, though Burton is questionable on this root. In the nursery there is some breakage of Grand Duke at the bud union, but very few break in the orchard.

The union between California Blue and peach is strong, but as the trees increase in age there is nearly always considerable dieback in the tops, and the trees are not long-lived, indicating that there is a lack of congeniality. The union between Diamond plum and peach root is not always strong; but those which survive the first years make vigorous and satisfactory trees.

Sugar and Robe de Sergeant prunes do not make very strong unions and seldom make satisfactory trees on peach root. In the nursery row Robe de Sergeant grows vigorously enough on peach root, but the union is very brittle; and its physiological uncongeniality is displayed by the fact that a number of the trees, after making vigorous growth, become chlorotic, wilt, and die. The rootstock problem of this variety is discussed on page 30.

Several growers in Sonoma County prefer to grow Imperial prune only on light soils where peach root can be used, because bacterial gummosis is too severe on this variety on myrobalan root in heavy soils.

Peach root is commonly used for the French prune. In total acreage it is exceeded only by the myrobalan-rooted trees. This is discussed in the section devoted to plum roots, page 25, and again referred to in the sections dealing with apricot and almond roots.

In light soils under irrigation French prune trees on peach root in many districts grow a little faster the first few years, begin bearing younger, and produce more and larger fruits for a number of years than they do on myrobalan root. This heavy bearing often causes early decline of the trees, which is particularly common in certain areas where there is a deficiency of available potash in the soil. However, even on myrobalan roots in fertile soil, prunes bear too heavily in such areas, and the trees will decline early unless proper measures are taken to prevent overbearing.

It has been observed a number of times that French prune trees on peach root in the Sacramento Valley grow larger water

sprouts in the interior and lower parts of the trees than do those on myrobalan. In old trees this is not so evident. When heavily pruned back, those on peach root make the greater response in growth of water sprouts. The trees start growth a little earlier in the spring, and the leaves are often paler for some weeks than on myrobalan root.

In Santa Clara Valley the choice on light soils under irrigation seems to be peach root, and on heavy or wet soils myrobalan. On heavy soils French prune trees on peach do not grow so fast as those on myrobalan. A few growers with irrigated orchards on light soils reported French prune on peach root to bear younger and with larger fruits than on myrobalan. Most of the growers there have not noted this difference. Apparently this is not so conspicuous there as in the interior valleys and north of San Francisco Bay. Several orchards were observed in which pole thinning of fruits was practiced in years of heavy crops. This was a rather rough clubbing process, whereby many leaves and spurs were unavoidably knocked off. By this means the size of fruits was increased and the trees left in a thriftier condition for production of the next year's crop.

In the area north of the Bay region, where overbearing on peach root is a problem, several growers report that they have been able to regulate the crop and prevent too great strain on the trees by thorough annual pruning-out of fruiting wood. In non-irrigated orchards on light soil young French prune trees on peach root grow faster and produce more and larger fruits than on myrobalan root; but with increasing age the heavy crops result in smaller fruits with less sugar content.

In Napa County on the lighter or well-drained soils, peach root is favored, and the trees have a reputation for living to a great age. Here orchards on myrobalan, in soils too heavy and wet for peach root, grow well but often fail to produce satisfactory crops. On the light, well-drained soils on myrobalan root they do not bear so well or produce such large fruits as on peach root. Bacterial gummosis has been common in some years on French prune. In one orchard this disease was much less severe on trees on peach root than on those on myrobalan.

Apricot on peach roots. Peach root for the apricot varieties is quite popular in some districts but not in others. It is difficult to sum up briefly the growers' reasons for rootstock preferences since they vary widely. Often trees have prospered or have failed on the various rootstocks because of soil, alkali, excess water, climatic influence, disease, insect pests, pocket gophers, and the like. The causes were in many instances imperfectly understood by growers; this fact directed the choices sometimes to advantage, sometimes otherwise.

Apricot trees have been known to grow faster in some places on peach root than on apricot root. The union between the apricot and the peach root is strongly knit, but at times it is enlarged or rough, and quite commonly the crown of the peach root is larger than the trunk of the apricot tree.

Though apricot trees on peach seldom break in the wind, they sometimes break at the union when pulled up by tractor. The break is jagged, not smooth as in the case of apricot on myrobalan root. The crown enlargement is seldom so great as in the case of apricot on myrobalan. The fact that the reverse combination (that is, peach varieties on apricot root) is not always satisfactory would seem to indicate that these two species are not completely congenial physiologically.

The difference in blossoming dates of apricots on the various stocks in some years may throw the one or the other into a weather period favorable to frost or to diseases, such as brown and green rot. In regard to blossoming time, perhaps the most common expression of opinion by growers is that apricots on myrobalan

and peach roots blossom earlier than those on apricot root, though in certain seasons the reverse has been reported. Blossoming dates were recorded at Davis with trees of Blenheim apricots on seven different rootstocks for 8 years. The difference in blossoming date with all these seven rootstocks is too complex to be analyzed here. Briefly, with the three commonly used rootstocks (myrobalan, peach, and apricot) all three groups of trees blossomed at the same time in 4 out of 8 years, and in all 8 years at least two of the three groups were in full bloom at the same time.

In 1929 those on apricot root blossomed five days later, and in 1934 those on myrobalan blossomed four days earlier than the other two groups. The blossoming date refers to full bloom. In some cases where there were differences in the date of full bloom, the first blossoms were early or late in proportion to the earliness or lateness of full bloom. In 1932 and 1933, with all seven stocks full bloom was almost simultaneous (within 2 to 3 days) and the first bloom likewise appeared on about the same day. In the other six years the blooming dates varied more or less widely among the seven rootstocks.

It is commonly stated that apricot varieties on peach root ripen a few days earlier than on apricot. Careful observation of Blenheim at Davis in 1935 and 1936 failed to reveal any differences in this respect. If there had been very striking differences in former years it would perhaps have been noticed. In 1938 the ripening dates of Blenheim on the seven stocks was as follows: *Prunus Besseyi*, June 24; myrobalan, Marianna, and peach, July 2; apricot, July 4; *P. Davidiana*, July 6, and *P. Mume*, July 8.

The size of the crop made no difference in ripening date, though heavy crops have occasionally been noticed to have a delayed ripening. Where the large crop was due to some weakness in the tree, such as partial girdling by pocket gophers or root borers, the fruit has been seen to ripen earlier. In the Davis orchard there were practically no differences in sizes of Blenheim trees on the three common rootstocks, those on apricot being slightly smaller. At 12 years the myrobalan-rooted trees had an average trunk circumference of 36.5 inches; those on peach and apricot roots measured 36.4 and 34.3 inches respectively. In some interior-valley orchards on deep loams and sandy soils, apricot trees are larger on apricot root than on peach, and the latter in turn are generally larger than those on myrobalan.

In the Winters district where apricot is planted mostly on peach there are some very old trees up to 85 years on this root. The preference for peach root was begun in early times in this district, apparently because of the opinion that shipping fruits ripened a few days earlier on peach than on apricot root and that the fruits were larger. Possibly, as at Arbuckle and in Capay Valley, those on peach withstood dry years better in unirrigated situations.

In the coastal valleys of central California there seems to be no difference in ripening dates and but little, if any, difference in age of coming into bearing of apricots on myrobalan, peach, and apricot roots.

There seems good evidence for the rather common belief among growers that apricot on peach, though long-lived, is shorter-lived than on apricot root. It has sometimes been reported than on light sandy soils under irrigation apricot on peach grows more rapidly when young and bears earlier, but that after coming into full bearing it does not bear so heavily as it does on apricot root. However, we have seen the reverse of these conditions, and in Merced and Stanislaus counties apricot on apricot root is generally reported to grow more rapidly.

It is also commonly stated by growers that apricot on apricot root, in order to be at its best, requires a more regular

water supply than on peach root; and a number of observations in Yolo, Colusa, and Solano counties indicate this is probably true. In unirrigated orchards in these districts trees on peach root prosper better than those on apricot root. This is particularly noticeable in dry years, and even following dry years those on apricot root tend to produce smaller fruits. The trees generally hold their leaves later into the fall than do those on apricot root. Myrobalan root is in disfavor for apricot varieties except in low areas too wet for the other rootstock. In irrigated orchards in the above districts there seems little preference between peach and apricot root, though one grower reported more rapid growth of trees on peach than on apricot.

On the more sandy soils throughout the San Joaquin Valley, many growers and horticultural authorities report that apricot on peach root has been more reliable than on apricot and myrobalan—those on the latter root being very frequently affected with bacterial gummosis (mostly the sour-sap type), and the apricot-rooted ones only a little less so. It is perhaps because of the peach-root borer that peach root has been so little used for apricots in the coastal valleys, south of the San Francisco Bay region.

Almond varieties on peach roots. A large percentage of the almond orchards in California are on peach root. Almond varieties on peach root are less frequently injured by excess water than they are on almond root. For this reason thousands of acres of almond have been planted on peach root in California in areas where there is danger of floods or of too slow surface drainage or poor downward percolation of rainwater.

Almond varieties usually grow more rapidly and bear more heavily the first few years on peach than on almond root. In the nursery they usually grow more rapidly and make trees more uniform in shape as well as size, and for this reason nurserymen prefer to grow them on peach root. They are not as long-lived as trees on almond root, and in many situations they begin to decline in vigor and in productivity after they are 15 to 25 years old.

The Texas variety has often been observed to decrease in vigor (on peach) at an early age. Almond trees on peach are not so drought-resistant as are those on almond root, and in unirrigated situations they begin much earlier to decline in vigor. In years of low rainfall, unirrigated orchards on peach root begin to show distress much earlier in the summer than do those on almond root. The decline in production of orchards on this root is accompanied by lack of vigor in growth of terminal shoots and foliage, and this takes place gradually over a period of years. As the decrease in vigor continues, the hulls are inclined to adhere too firmly to the nuts at harvest time, especially in unirrigated or otherwise adverse conditions.

Almond trees on peach root do not do well on soils of high lime content. They withstand excess soil moisture a little better, and for this reason growers sometimes use peach root in the low spots and the more slowly drained, heavy soils—even though almond root is being used for the orchard as a whole. In one section where there is a highwater table some growers use peach root and have attempted to get along without irrigation. However, observations indicate that even with the water table 5 to 6 feet from the surface, irrigation is usually distinctly beneficial.

At least the main roots of almond trees on peach do not penetrate the soil so deeply as those of almond root. The difference in root anchorage was particularly noticeable in the severe windstorm which occurred in central California in February, 1938, when those on peach blew over much more frequently than did those on almond root. This difference is also very apparent when growers pull up trees with a tractor.

Some growers have chosen peach root because it is not so susceptible to crown gall, and it is easier to secure a complete stand of trees on peach root. Once established on almond root, the trees are not so severely injured by this disease as are those on peach root, even though there are more galls on the almond root.

The graft unions between almond varieties and peach root are often rough, and usually the almond grows somewhat larger in diameter than the peach trunk immediately below the union. However, the reverse situation is occasionally observed.

Almond varieties grow well on seedlings of the nematode-resistant peaches Shalil, Yunan, and Bokhara. There are no orchards on Stribling's S37 of sufficient age to determine the usefulness of this stock for almond varieties.

Other peach species as rootstocks. Seedlings of the Chinese wild peach, *Prunus Davidiana,* have been proposed as a rootstock for adapting orchards to alkali soils or for alkali spots within an orchard. In the coastal plains of Eastern Kiangsu, China, it tolerates alkali soils remarkably well, according to plant explorers and Chinese authorities.*

Observations of a few plantings in California indicate that this root has not, in all cases, been very satisfactory as a rootstock even where alkali is not a factor. Alkali spots within an orchard are often areas of soil conditions that would not be congenial, at least to common peach root. They are usually low and poorly drained. However, peaches on this root in alkali soil have grown better than those on common peach root, though not always satisfactorily.

In regard to the tolerance of this species to excess soil moisture observations are very limited. In a low, wet spot in a Napa County orchard one test plot had four seedlings of this species and a number of myrobalan and St. Julien seedlings. The first winter after planting, all the Davidiana trees died, though none of the plum seedlings were injured. Chang (1935) reports that in China it is not more tolerant to excessive soil moisture than common peach seedlings.

The most common difficulty with this root is its extreme susceptibility to crown gall. In several peach orchards on soils too alkaline for common peach roots, the trees were reported to be small for their age and the scion variety overgrowing the root. In one orchard this dwarfishness was apparently, at least in part, due to severe crown-gall infections.

Seedlings of *P. Davidiana* in our nematode-resistance test nursery were not severely injured by the root-knot nematode, though quite thoroughly infested. They made very vigorous growth and thus apparently tended to be fairly tolerant if not partially resistant to this nematode.

One orchardist at Delhi, California, planted several hundred Davidiana seedlings in very sandy soil, and practically every one became infected with crown gall. This disease, combined with root-knot nematode and little-leaf (zinc deficiency), within two years ruined nearly all of them. The few remaining ones grew well, and we top-worked them to Paloro peach when they were about four years old; these made good trees, though they are moderately infested with nematodes. At Delhi a nursery row consisting of 100 seedlings of Davidiana and an equal number of common peach seedlings were planted, alternately in the row, and none of the peach seedlings contracted crown gall, where as 96 of the Davidiana trees were affected.

Seedlings of this species are very susceptible to infection by the oak-fungus root rot.

Observations in orchards indicate that many plums and prunes overgrow this stock and do not make good unions. Tragedy plum grew well on this root in

* Personal report to the author June 23, 1931, by W. T. Chang of the National University of Chekiang, Hangchow, China.

an orchard in Placer County. The graft union is smooth and apparently strong. French, Robe de Sergeant, and Sugar prunes make poor unions and overgrow this rootstock.

At Davis in 1925, 1926, and 1927, a few stone fruits (2 trees each) were planted on Davidiana seedlings, 24 feet apart in rows 12 feet apart. The almonds, Nonpareil, Ne Plus Ultra, Texas, I.X.L., and Drake made exceptionally large trees. Wood (1947) states that elsewhere plantings to date have been somewhat unsatisfactory "partly because the Davidiana is highly susceptible to crown gall." Moorpark, Blenheim, and Newcastle apricots grew normally, though the unions broke easily and the scion trunks have grown faster than the root crown. Paloro, Ontario, Elberta, Early Crawford, and Muir peaches made good unions and normal growth. French, Sugar, and Coates 1418 prunes and Santa Rosa and Beauty plums grew normally, though each was slightly enlarged immediately above the union. Gaviota plum was greatly enlarged above the union, and the tree was rather small for its age; so also with the California Blue plum. The latter variety reacts in the same way with common peach seedlings.

The bark of the roots of this species is not yellow inside like that of the peach, but is whitish to pink like that of the other common rootstock species. An attempt to grow vegetatively (by layering) a vigorous nursery seedling of this species failed after several years of trial.

Another wild peach of the Orient is *Prunus mira.* It is fairly vigorous and in our nurseries was quite free from crown gall. At the Riverside Experiment Station, Smith (1925) by artificial inoculation found it fairly resistant to the crown-gall bacteria. In test plots, in oak-root fungus areas in Napa and Placer counties, it was the most readily attacked of any of the stocks tried, including *P. Davidiana.*

The following varieties made good unions in the nursery with seedlings of *P. mira:* Climax and Clyman plums, French prune, Blenheim apricot, Elberta peach, Nonpareil and I.X.L. almonds.

Preliminary tests at Davis indicate that the dwarfish Desert Peach (*P. andersoni*), seeds of which were gathered in Mono County, California, does not make a strong union when grafted onto some of the common peaches. However, 6-year-old scions of the species are growing normally at Davis on seedlings of myrobalan, peach, apricot, and almond. The Kansu peach from Kansu Province of China (*P. Kansuensis*, P.I. 4004) is another vigorous species. As with *P. mira* and *P. Davidiana*, the inner bark of older trees is not yellowish as it is with common peach and nectarine. Two 2-year-old trees in the orchard were top-worked to Paloro and Hauss Cling peaches. The peach scions, now 4 years old, have made good unions and normal growth.

IX. APRICOT ROOTS FOR STONE FRUITS

Seedlings of the common apricot (*Prunus Armeniaca*) are satisfactory as rootstocks for apricots and for some plums and prunes. The seedlings of some varieties are successful with some peaches and have been used for shipping varieties in sandy areas where the root-knot nematode is a serious pest. Almond varieties do not make strong unions with apricot seedlings. Identification of apricot roots is discussed on page 4.

Most nurserymen have in recent years been using only the seeds of the Blenheim variety as a source of apricot seedlings. In nursery tests at the Davis Station, peach varieties grew more normally on Blenheim than on Tilton, Moorpark, and Montgamet seedlings. Unfortunately in earlier nursery practice the seeds of Tilton were used because they made more vigorous nursery seedlings than did seeds of Blenheim and other common varieties.

A test of seedlings of 50 apricot varieties in the nursery at Davis indicated that none of the common varieties make better

nursery stock than the Blenheim—if as good. Tilton, Superb, Catherine, and Alexander made the most vigorous seedlings of all, but except for Tilton they were not tried for affinity with peaches, plums, and prunes.

Tests indicate that apricot does not propagate readily by either stem or root cuttings nor by layering and stooling.

Apricot varieties on apricot roots. There are no available statistics showing the present trend in rootstocks used for the apricot. Inquiries among nurserymen, growers, county farm advisors, and agricultural commissioners indicate that there are less myrobalan and more peach roots used in comparison with apricot. Possibly under conditions favorable to apricot root the apricot varieties perform more normally on roots of their own species. To fit the apricot varieties to special soil, climate, and cultural conditions, and to certain diseases, growers have learned to substitute other rootstock species.

In the central coastal districts apricot is the preferred root at present, though some trees are on myrobalan. Throughout the central valley districts and the surrounding hill country, peach root is used more freely than the apricot, and the use of myrobalan is confined almost entirely to wet soils and areas of high water table. In the sandy soils of the interior valleys peach had become the favorite rootstock until the widespread introduction of the root-knot nematode several decades ago. The recent discovery of peach roots partially resistant to nematodes will perhaps again encourage the use of peach in place of the nematode-resistant apricot root.

In heavy soil on the west side of the San Joaquin Valley in Stanislaus County, apricot trees on apricot root grow larger and do better than those on peach root. Apricot root, though more sensitive to wet feet than peach root, is more resistant to crown rot so that apricot on apricot root often survive wet situations better than apricot on peach root.

In unirrigated orchards in the central coastal areas, apricot trees on peach root are more resistant to drought and are longer-lived than those on apricot root. Trees on peach root are much less subject to attack by pocket gophers and field mice than are those on apricot root. Some growers are careful to plant with the graft union above the soil line to keep the apricot trunk out of the way of these rodents.

Other reasons for preferences of some growers to peach root for apricot trees are discussed on page 53.

The prevalence of bacterial gummosis and of brown and green rots in apricots in relation to rootstocks are discussed on pages 11 and 12.

Peach varieties on apricot roots. Apricot root has occasionally been used as a stock for peaches, but this combination has not always been satisfactory. Mostly this stock has been used in the sandy soils of the interior valleys, where the root-knot nematodes precluded the use of peach root. There is much evidence that seedlings of Blenheim apricot make better rootstocks for peach varieties than do seedlings of the Tilton variety, which had been used by many nurserymen until within the past 15 or 20 years. This might explain some of the varying degrees of success of the older peach orchards on apricot root.

In the test nursery at Davis, Elberta peach grew much better on Blenheim than on Tilton seedlings. While some of the older orchard plantings in the state performed well up to 20 or 25 years of age, others began to decline in vigor at 10 to 15 years. Peaches on apricot were not so vigorous as those on peach root, though some varieties when young grew as rapidly as those on the latter root. When transplanted to the orchard a number of the nursery trees on Tilton seedlings usually failed to grow or else died back after making a good start; thus several years were required to get a complete stand of trees. It was particularly nursery

trees with but few fiber roots and ones without lateral roots that failed to grow when transplanted to the orchard.

At Davis the following peach varieties (2 trees each) were doing well on Blenheim seedlings when taken out at 14 years of age: Alexander, Briggs Red May, Elberta, Hauss, Lemon Cling, Levi, Lovell, Mayflower, Ontario, Sims Cling, Strawberry Cling, and Susquehanna. Mayflower, Lemon Cling, and Hauss Cling were rather small, but the others were of normal size. The peach scion had considerably overgrown the apricot root in the case of Elberta, Hauss Cling, Lemon Cling, Lovell, and Susquehanna; and with the following the root crown was much larger than the scion trunk: Alexander, Briggs Red May, Mayflower, and Strawberry Cling. Most varieties compare favorably in growth on Blenheim apricot seedlings to those on peach root nearby.

Orchards of the following peach varieties on apricot, nursery budded, have been reported by growers, county farm advisors, and agricultural commissioners, as doing fairly well: Elberta, Levi, Lovell, Muir, Orange, Paloro, Salwey, Sims, Selma, Socala, and Tuscan. In Kern County and in sections in southern California a number of early-shipping varieties have been growing fairly satisfactorily on Blenheim apricot root in nematode-infested sandy soil. One large operator reported that they did not do so well on Tilton seedlings.

In one orchard in Kern County, apricot seedlings (parental variety unknown) were planted in the orchard and later topworked to Elberta. The latter overgrew the apricot seedlings considerably, but only a few trees seemed to be harmfully affected thereby.

Plum and prune varieties on apricot roots. Considering all factors, some plums and prunes are not so satisfactory on apricot root as on peach and myrobalan. Because of the root-knot-nematode infestation in very sandy soil of the interior valleys many plum orchards have been planted with apricot root in recent times. The greater number of these are in Kern County, where there are many excellent orchards, principally of Japanese plum varieties.

Our data indicate that the following plum and prune varieties are usually satisfactory on apricot root: Becky Smith, Burbank, Burton, Formosa, French Giant, Golden Drop, Grand Duke, Hungarian, Imperial, Ogon, President, Quackenboss, Santa Rosa, Tragedy, Standard, Sugar, Wickson, Yellow Egg.

Nearly all plum and prune varieties overgrow this stock more or less, and some are easily broken at the unions. If the unions become covered 6 or 8 inches below soil level practically all the Japanese plums develop large scion roots. The European plums and prunes are not so prone to scion-rooting when on apricot root as are the Japanese.

French and Standard prunes, while not making strong unions, are usually satisfactory—only occasionally is the wind breakage serious. Sugar prune on apricot root usually does well.

At Davis an orchard was recently taken out consisting of two trees each of 43 varieties of plums and prunes on apricot, peach, almond, and myrobalan roots, ranging from 14 to 16 years of age. It was noted that more of the European varieties made small trees on apricot root than did the Japanese varieties. The Sharpe Plumcot hybrid is doing well on apricot root.

Beauty, Gaviota, El Dorado, and Duarte make weak unions with apricot root, but grow thriftily. Amador does not succeed very well on this root, but Becky Smith grows very vigorously on it. Kelsey is only moderately thrifty, and the wood union is not strong. In an orchard in Kern County, apricot seedlings were topworked in the scaffold branches to Santa Rosa plums, and these have done very well.

A number of French prune orchards are on apricot root. One in Sonoma

County, over 50 years old, was still in good condition and bearing larger fruits than those on myrobalan. Very few broke at the union after they attained mature stature, and there are not many trees missing in the orchard. Occasionally in other districts some breakage at the union occurs, but except in a few instances it has not been serious.

In San Benito County a number of orchards of French prune have been planted on apricot root, and of sugar prune on apricot in Santa Clara County. In one orchard in Santa Clara Valley, bacterial gummosis was observed to be much less severe on Sugar prune on apricot than on myrobalan root.

Both Sugar and French prune trees on apricot root were more easily blown down than were those on myrobalan root in the strong wind storms of February, 1938. French prune trees on almond root were not uprooted, even though the main branches of a few were torn off. Some French prune trees on apricot root were broken off at the union, but none of the Sugar prunes on this root were thus broken. In all cases the prune (both French and Sugar) trunk had grown faster than the apricot root crown, and in some cases the constriction was so great that in a windstorm the trees broke off beneath and not through the union.

On page 15 is a discussion of the French prune on apricot compared to myrobalan, peach, and almond roots, under non-irrigated conditions.

Other than two trees at Davis the Station has no record of orchards of Robe de Sergeant on apricot root in California. The trees at Davis at 18 years had outlived those on peach and myrobalan roots planted at the same time. They tend to bear too heavily in interior valley conditions, and will die back at the tips if the excess fruits are not thinned. This thinning was successfully done at Davis by poles.

In two nematode-resistant test plots in Kern County, 5-year-old Robe de Sergeant trees on Blenheim apricot seedling roots were growing well when the grower pulled the whole orchard. In the same orchard President plum trees on apricot root, 5 years old, were doing well on this root but not growing so rapidly as those on the vigorous Marianna Selections 2623 and 2624.

In an orchard in Madera County, two Santa Rosa plum trees on apricot root were not affected by "little leaf" (zinc-curable type), whereas all adjacent trees of the same variety on peach root required regular treatment for this trouble.

Almond varieties on apricot roots. Because almond varieties make very weak unions with apricot seedlings, few almond trees have been established on this root. Test trees at Davis made satisfactory growth, but the unions were so weak that many broke at the union while being taken up, or while being planted in the orchard. After planting, most of them grew well until they broke in the wind. One specimen (Texas variety) grew for 13 years, bore heavily, and had a trunk diameter of 12½ inches when it broke off in a strong wind. The only other one surviving to 18 years of age is an I.X.L. tree. It grew normally for 9 to 10 years but then began to decrease in vigor and thereafter made practically no new terminal growth; in fact, some terminals died back several inches. The almond trunk distinctly overgrew the apricot root at the graft union.

Growers have proposed the use of peach as an intermediate stock between apricot root and almond varieties in sandy soils infested with root-knot nematode. This combination was observed over a period of 15 years, beginning at the time the trees were planted in an orchard near Delhi, Merced County. Most trees in the sandy spots in this almond orchard are on Bokhara, Shalil, and Yunnan peach roots. Those on apricot root with peach (variety not known) as an intermediate stock grew fairly well, though many were killed by bacterial

gummosis, which attacked the apricot root crown. The union with peach was some inches above ground. If the unions had been kept below ground, it is not likely that they would have become infected with this disease.

Other apricot species used as rootstocks. The Japanese apricot (*Prunus Mume*) has aroused much interest as a rootstock because of its resistance to crown gall (as reported by Smith in 1925), root-knot nematode, and rumored resistance to oak-root fungus. Years ago it was planted by growers as replants where this root rot had killed trees of various stone fruits in their orchards. Its resistance to this disease appears about comparable to that of the more resistant myrobalans or possibly even less so. In some cases they began dying of the disease within two to three years, while in others the trees stood much longer before they died, and some are persisting after 15 years or more. Where growers had planted seedlings of this species, not many contracted the disease until after they were top-worked to plums, prunes, and apricots.

Tests indicate that *Prunus Mume* is quite resistant to the root-knot nematode. Chang (1935) reports experiments in China which indicate that seedlings of this species are more tolerant of excess soil moisture than are those of common apricot, peach, almond, and *P. Davidiana.*

In the Davis orchards apricot varieties are the only ones that have made good unions or that have not grown very slowly on *Prunus Mume* root. Peach, plum, prune, and almond varieties have made poor unions and dwarfish trees. The Japanese apricot itself is a small tree and the seedlings vary greatly in vigor, some being distinctly dwarfish. If it is to be used at all, it would apparently be advisable to try the Blenheim or Royal apricot as an intermediate stock for peaches and for such varieties of plums and prunes as will top-work upon apricot.

At the Davis Station the following apricot varieties did well on *Prunus Mume,* and at 12 years of age were as large as comparable trees on common apricot root: Blenheim, Tilton, Newcastle, and Yakimene. The following plum varieties used in this test did poorly: French, Sugar, Coates 1418, Imperial, Diamond, and Burbank. French, Gaviota, Imperial, Giant, President, and Wickson on *P. Mume* are doing poorly in orchards elsewhere. Elberta and Paloro peaches greatly overgrew the Mume stock, were very dwarfish, and suckered badly from below the union.

In one orchard at Hollister the peach-root borer (peach-tree borer) has killed 2 out of 5 test trees in an oak-fungus area, and the remaining 3 are severely affected —indicating that it is very susceptible to this pest, though in this orchard these tests trees have resisted oak-root fungus for 15 years.

At the Riverside Experiment Station, Smith (1928) tested *P. Mume* as a rootstock for a large number of stone fruits and found that it did not offer much promise as a stock for any of the stone fruits except the apricot, for which apparently it can be safely used.

The surface color of the roots of the Japanese apricot is not so bright a red as that of common apricot. The lenticels have much internal white tissue, similar to that of the roots of plums.

Blenheim apricot on the Desert Apricot (*Prunus fremonti*) has made semi-dwarfish trees in experimental tests at the Davis Station. It has also been tested for resistance to oak-root fungus and found quite susceptible. The strain of this species used for the tests may possibly be a hybrid, though its fruits and leaves compare favorably with those of wild shrubs collected east of the Sierra Nevada Mountains. It was selected from seedlings grown from seeds of a shrubby tree planted in the orchards at Davis. Its extra vigorous growth indicates that it may be a hybrid. It propagates readily by stem cuttings. The surface color of the roots

of the desert apricot tree is brownish.

Also in the Station's oak-root fungus test plots there is the Purple or Black apricot, *Prunus dasycarpa,* of northern Asia, grown from cuttings of the named varieties of this species, Florizan and Black. In the nursery French prune and Nonpareil almond made good growth on it, but the almond trees made such weak unions that they broke off while being dug. Elberta peach made very dwarfish growth upon this stock. Florizan made strong unions and normal growth when budded upon seedlings of apricot, myrobalan, and St. Julien. On peach and almond seedlings it made vigorous growth, but the unions with almond were very weak. Tests at Delhi indicate that it is resistant to the root-knot nematode.

X. ALMOND ROOTS FOR STONE FRUITS

Almond root is more commonly used for the almond varieties than for other stone fruits. Some plums, prunes, and peaches grow well upon this root. In unirrigated soils its deep-rooting habit seems to give the trees considerable drought resistance, though its greater susceptibility to crown gall in some areas sometimes causes difficulty in establishing orchards on it.

Almond root in relation to various diseases and pests, relative tolerances to alkali, salt, lime, excessive soil moisture, depth of rooting, etc., is discussed in earlier sections. Its apparent slight tolerance to alkali salts is discussed on page 22 and to boron on page 23.

Ways of distinguishing almond roots from the roots of other stone fruits in the nursery and orchard are discussed on pages 4 to 6.

Though making better growth in loamy and sandy or gravelly soils, yet almond roots will grow in fairly heavy soils if surface drainage and downward percolation of water is sufficient to avoid waterlogging of the soil in the root zone and about the trunk.

Sources of seed and propagation of almond rootstocks. Nurserymen in the early days usually used seeds from stray trees of bitter and of hard-shelled seedlings rather than seeds of commercial orchard varieties. Apparently this preference was based on the cost of seeds rather than on any proved superiority of orchard trees propagated upon them. In the past few decades most nurserymen have used seeds of the Texas variety. These give uniform seedlings for their nursery purposes. No conclusive evidence has appeared in old orchards to show that trees on Texas seedlings are either better or worse than those on seedlings of other varieties, or those on bitter, or hard-shelled seedlings.

There seems no evidence to substantiate the opinion that seeds of the bitter almond make better seedlings for rootstocks than do those of the sweet varieties of commercial almonds. There is apparently no difference in resistance to red spider in the nursery nor to the attack of the pocket gopher in the orchards. The latter will attack and girdle almond-seedling roots as readily as it does apricot, regardless of whether the seedlings were grown from seeds of bitter or sweet almonds. When the seeds of a sweet almond tree are planted, some of the resulting seedling trees will produce seeds with bitter kernels and some of them will produce seeds with sweet kernels; conversely, some seedlings from bitter almonds produce sweet and some bitter kernels. Some will be soft-shelled and others hard-shelled.

Of course it is possible there are individual bitter and hard-shelled trees, the seeds of which might produce good rootstocks. However, no evidence has come to the attention of the Experiment Station pomologists that such has been demonstrated. Some nurserymen find them unsatisfactory partly because each bitter tree produces seedlings of different vigor; hence the trees in the nursery are very irregular in size.

There seems no foundation for the opinion occasionally expressed that fruits of sweet almonds grown on bitter roots have a slightly bitter taste.

In the nurseries at Davis seeds have been planted from a number of bitter trees as well as all the common commercial varieties, and crosses between many of the latter. The most promising from the nursery standpoint seem to be Texas, Drake, Ne Plue Ultra, Marcona, and Harriott. Texas seedlings are good, and most nurserymen use them. Seedlings of Drake sometimes have so many fine twigs near the ground that preparation for fall budding is more difficult than with Texas seedlings. However, this might be a valuable characteristic for early June budding in which twigs below the bud are advantageous. The Nonpareil is more particular in its grafting affinities than the others, and we have seen it more severely affected by bacterial gummosis and crown rot than some of the other varieties. Its seedlings if used as rootstocks might possibly also have these weaknesses.

Seedlings from seeds of two bitter-almond trees growing at Davis have been much more readily infected with the crown-gall organism than have those from Texas seeds. The peach-almond as a rootstock is discussed on page 47.

Attempts at growing almond by layers and by stem cuttings have not been successful. A small percentage of root cuttings sometimes grow. In one test at the Davis Station root cuttings obtained from a miscellaneous lot of seedlings gave a stand of 20 per cent. The next year the roots of these were made into cuttings and planted as before, and only 2 per cent grew. Some special procedure might be developed to cause a greater rooting response, if it should be found desirable to propagate a nematode-resistant almond seedling selection vegetatively instead of by seed.

Other almond species used as rootstocks. The common almond is the only almond species used as a rootstock in California, but there are shrubby species used as ornamentals. A shrubby species known as the Desert Almond, *Prunus fasciculata,* is native to southern California (mostly in desert areas) ; but it has not apparently been utilized even as a dwarfing rootstock. The writer has grafted a specimen of this species at Davis upon a large I.X.L. almond tree. At four years it was growing well, though dwarfishly, but died in the fifth year, possibly shaded out by the more vigorous ungrafted branches of the I.X.L. tree. Plants of the Desert Almond from the Mohave Desert have recently been taken to the Davis Station for genetic and other testing work.

Almond varieties on almond root. Approximately one half of the almond orchards in California are growing on almond root—practically all the others being on peach root. Only on heavy, wet soils or in areas of fluctuating high-water tables have plum roots been tried. Low, wet spots in almond orchards are frequently planted to trees on peach and plum roots. In wet situations almond root has two characteristics which count against its success—its deep-rooting habit and its sensitivity to infection by crown-rot fungi. The use of peach root for almonds is discussed on page 55.

The almond varieties usually make inconspicuous unions with almond seedling roots. However, there are many exceptions; for instance there have recently been taken out Languedoc almond trees approximately 70 years old on almond root with greatly enlarged crowns below the unions (fig. 24). The origin of the almond root in this orchard is unknown. Two of those that had suckered below the union have borne small nuts with sweet kernels. This great overgrowth of the root crown has apparently had no ill effects upon the health of the trees, but the largest, most vigorous one was without this enlargement. The tree on page 64 bore regularly as much as 400 pounds of shelled nuts.

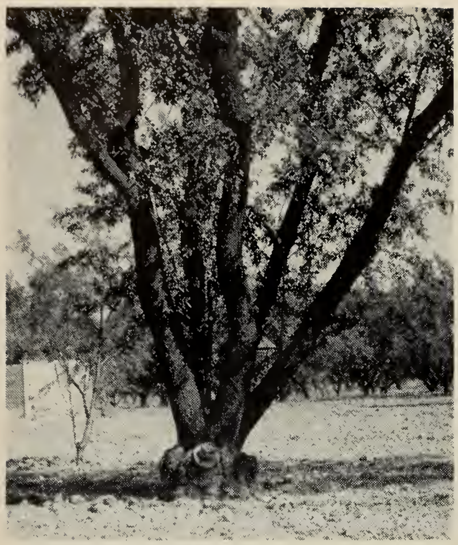

Fig. 24. Languedoc almond 70 years of age on almond root. Note that the rootstock has grown much larger than the Languedoc trunk. Diameter of trunk at narrowest place is 30 inches, and diameter of crown one foot above ground is 50 inches. The tree has declined in vigor in recent years.

In the Sacramento Valley practically all the older almond orchards are on almond root. In recent years there has been some trend toward peach root, especially in moderately wet areas.

Peach root has been more commonly used in recent times in the irrigated sections of the north San Joaquin Valley, almond root in the foothill districts. The preference for peach root is partly due to the greater susceptibility of almond roots to crown gall and to the fact that on peach root the trees grow faster the first few years and bear more heavily at least the first 15 or 20 years.

Some growers have believed that with a water table 5 or 6 feet below ground (which never rose higher during the growing season) irrigation was not essential. Our observations indicate that these trees showed too much distress after the moisture in the surface zone was extracted by the roots.

In Capay Valley, Yolo County, the almond varieties have performed much better on almond than on peach, whether irrigated or not. The experience of growers there indicates that if the soil is too heavy and wet for almond root, it does not pay to substitute either peach or myrobalan (page 25) root. The more congenial Marianna 2624 root is being tried in these situations. In unirrigated orchards, trees on almond root show much greater drought resistance than those on peach. Almond trees on almond root, in an orchard with a water table at 10 to 15 feet below the surface, have made unusually large trees at 35 years of age. Yet in the drought year of 1939 (rain penetration 1 to 1½ feet) the trees were showing distress by the first week in June. In this orchard 8-year-old trees had sent out roots as far as 28 feet from the trunk at a depth of 18 inches.

In the Brentwood district of Contra Costa County, almond root is largely used except in wet and heavy soil. Peach is used in the latter areas. In these situations it makes larger trees than those on almond root, and the trees bear early and well. There has been some injury to almond trees here on peach root in wet situations.

In the nonirrigated Paso Robles almond district, San Luis Obispo County, almond root has proved best. In areas of high lime content, peach-rooted trees have performed very poorly in that district.

Peach and nectarine varieties on almond roots. Though there are peach orchards on almond root doing well, the almond has not been generally satisfactory as a stock for peach, and few commercial orchards have been planted on this root in recent decades. The trees are often smaller, with a few varieties distinctly dwarfish and shorter-lived than on peach root.

The wood union between peach varieties and almond root is usually strong, though the bark union is sometimes rough and apparently the cause of poor health.

Identification of peach trees on almond root is quickly determined in the orchard by methods described on page 6.

Peach-root borer (in certain coastal districts) and crown gall are much worse with peach on almond root than on peach root, and these factors often cause the trees to grow poorly.

In one orchard of Tuscan peach on almond in Hollister Valley, San Benito County, on a rather heavy soil the peach-root borer was much worse than it was on peach root. The fruit on these trees ripened about one week earlier than on the adjacent trees on peach root. Earliness of ripening may have been due to the partial girdling effect of the borers rather than to the influence of the rootstock and graft unions. Growers occasionally report peach varieties ripening earlier on almond than on peach root. Christien (1934) reports that in Morocco peach is used on almond root in dry, stony, and calcareous soils, and earliness in ripening is common.

Twenty-one varieties of peaches on almond root were recently pulled out from the orchards at Davis. These were planted in 1925, 1926, and 1927. At the same time similar trees were planted on peach, apricot, and myrobalan roots for comparison. Circumference measurements after 10 years showed that about one half of the varieties on almond had not grown so rapidly as those on peach root. However, there were too few trees of each variety to draw definite conclusions. Apparently crown gall was partly responsible for the poor growth of some of these trees. One Alexander died at 10 and the other at 12 years of age. Both Mayflower trees died at the end of the eleventh year. Of the 5 Elberta trees, one died at the end of the tenth and one at the end of the twelfth year. Two of the others, at 14 years, were dwarfed, and the fifth was dying back in the top. At the end of the fourteenth year, the tops of some other varieties were dying back at the tips of the branches. Those which have done especially poorly are Alexander, Elberta, Hauss, Heath Cling, Lemon Cling, Phillips Cling, Salwey, and St. John. Apparently much of the dieback was due to crown-gall and wood-rot infections originating in old crown-gall tumors. Observations of peach varieties top-worked upon mature almond trees at Davis indicate that the following might not do well upon almond seedling roots, nursery-budded: Briggs, Early Crawford, Heath Cling, Florence, Foster, J. H. Hale, Mayflower, Miller Late, Muir, Peak, Phillips, and Tuscan.

In Victoria, Australia, Davey (1929) reports that almond makes the best stock for peach in very poor sandy soil "owing to its strong-growing root system, which gives it a greater range of root pasturage." The peach varieties concerned were not listed.

Observations are not available on nectarine on almond-seedling roots. Judging from the good performance of a few almond trees top-worked to nectarine varieties at Davis, they would perform about the same as peach on this root. Quetta and Stanwick top-worked upon Nonpareil were not very vigorous.

Plum and prune varieties on almond roots. Inspection of the tables of rootstock adaptabilities of plum and prune varieties found on page 69 reveals that some plums and prunes do not do well on almond-seedling roots. Robe de Sergeant prune and California Blue plum (*Prunus domestica*) fail completely on this root, while a number of others such as Climax, Sugar, and Burton seem to lack affinity with some individual almond seedlings although with others of the same nursery lot they make successful trees.

Little information is available regarding the success of a number of the plum varieties on almond-seedling roots. Their success may be judged somewhat by their behavior when top-worked upon almond varieties. Heppner and McCallum (1927) of this Station reported that top-working the following plums and prunes on estab-

lished almond trees in the orchard is not always successful: Burbank, Burton, Climax, California Blue, Diamond, Gaviota, Imperial, Kelsey, and Santa Rosa. Accordingly it would appear unsafe to use almond-seedling rootstock for these varieties without more extensive field observations.

One orchardist in Sacramento County top-worked Drake almond trees to Santa Rosa and Beauty plums. The Santa Rosa trees grew well, and beginning the fourth year bore well for many years; whereas most of the Beauty trees, though growing well and also starting to bear well, suddenly died in the fourth year. At Davis two trees each of Santa Rosa and Beauty 12 years old on almond-seedling roots are growing normally and producing well—bearing large fruits of good quality.

At the Davis Station in 1932 branches of 48 almond trees (Nonpareil, Drake, Texas) 10 years old were top-worked to 53 varieties of plums and prunes. The performance of the following indicate that it would not be safe to use them on nursery almond seedlings without further observation of their behavior in established orchards: Anita, Amador, Beauty, California Blue, Climax, Elephant Heart, Emilie, Gaviota, Italian prune, Jefferson, Kelsey, Pond, Robe de Sergeant, Simon (*Prunus Simonii*), Sachem, Sharkey, Sugar, Uncle Ben, Wickson, and Yellow Egg.

At the Davis Station one or two trees each of 27 plum and prune varieties on almond-seedling roots were recently pulled out at 14 years. A comparison of the circumferences of these varieties on the various rootstocks shows that most of them have grown satisfactorily. The California Blue trees were still healthy, though somewhat undersized, and with a bulged union. Nine trees of Climax (on almond root) were originally planted, and some grew poorly, indicating it is not a safe combination.

Two trees each, of the following were growing well: Sugar, Wickson, and Yellow Egg. The following show at least some weakness: Gaviota, Italian prune, Kelsey, and Pond. One of the two Coates 1418 prunes was unhealthy.

The above few plum and prune grafts and trees on almond seedlings are of course not sufficient evidence, but in the absence of more data they at least serve to indicate tendencies.

A myrobalan seedling grafted upon a Texas almond tree made a good union, whereas upon the Drake it made a poor union — indicating that upon almond nursery seedlings the affinity of myrobalan might vary from seedling to seedling, just as do almond varieties on myrobalan.

Plums generally tend to overgrow the almond but not so conspicuously as they do apricot root. They are not so prone to scion rooting as they are on the apricot root, and the wood union is usually structurally strong—there being little tendency to wind breakage. Plums tend to bear heavily on almond root, and at Davis some varieties have shown a tendency to weak growth, apparently due to overbearing. This is especially noticeable in the case of Climax, Gaviota, Giant, Kelsey, Pond, and Tragedy.

In Placer County a few growers report that President does better on almond than on myrobalan and peach roots, and one grower reports that his fruit ripens about 5 days earlier on almond. If this is true, it would perhaps indicate a weakness and possibly make for short-lived trees. However, in Alhambra Valley, Contra Costa County, old President trees are doing well top-worked upon Nonpareil, Drake, and I.X.L. almonds.

Diamond plum trees usually grow well on almond, though in at least one orchard in Placer County the fruit was of poorer quality on this than on myrobalan root. Top-worked upon Nonpareil and Texas at Davis, Diamond has grown well and produced fruits of excellent size and quality.

Many profitable old French prune or-

chards are on almond-seedling roots. Young trees on this root generally grow faster than on myrobalan. In Sonoma, Napa, Santa Clara, and San Benito counties trees from 50 to 75 years of age are holding up fairly well though (except in nonirrigated situations) perhaps not so well as those on peach and myrobalan roots. They bear heavily, with fruits usually larger than on myrobalan. However, as with peach root, in the interior valleys their early heavy bearing brings on early decline of the trees.

In Santa Clara Valley a number of growers report that French prune trees grow faster and bear larger fruits on almond than on myrobalan root, and some prefer the former root except in wet situations. In the hilly and other unirrigated and well-drained soils around Santa Clara Valley, French prune does very well on almond root, even on quite heavy soil, and it endures drought years better than on either myrobalan or peach root. Most of the orchards here are on myrobalan root. In certain districts where the soil has a very high lime content, almond root is the only stock showing practically complete freedom from chlorosis.

Indications are that this root should be avoided in districts where the prune is inclined to overbear, especially if there is also a deficiency of available potash in the soil, as in certain sections of Sacramento Valley.

In one French prune orchard in San Benito County it was observed that in years of severe fruit drop following prolonged hot weather some weeks before harvest time, the drop was much less on almond-rooted trees than it was in the case of those on myrobalan root.

Growers in Sonoma County favor myrobalan and peach root over almond for French prune. Myrobalan is favored for sugar prune and peach for Imperial, though some experienced growers prefer myrobalan for the latter. Though the union is strong between almond root and Imperial prune, this variety often overgrows this root conspicuously. Good orchards of this variety on almond root have been observed, but in most fruit districts Imperial prune seems to be at its best on myrobalan root.

French prune trees on almond root were more subject to crown rot under basin and contour irrigation on heavy soils in the central coast districts than they were on peach root, those on myrobalan being still less subject to this disease.

In our nursery at Davis, Texas almond seedlings grew much larger in diameter than the following species budded onto them: *Prunus americana*, *P. angustifolia*, and *P. nigra*. The following species overgrew (at least slightly) the almond stocks: *P. salicina* (most varieties), *P. domestica* (most varieties), *P. cerasifera*, *P. bokhariensis*, *P. mexicana*, *P. Simonii*, *P. Munsoniana*, and *P. subcordata*.

Apricot varieties on almond roots. Since apricot makes a very weak union on almond, few trees have been established upon it by fruit growers. Many break at the union in the handling from nursery to orchard, and in the orchard they are always subject to wind breakage. A bale of nursery trees of apricot on almond root was once observed by the writer in which over half the unions had broken completely—apparently at the time the ropes were drawn tightly about the packing material. In our experimental orchard at Davis some trees died during the first year, after making considerable growth.

Occasionally almond is reported successfully used as a rootstock for apricot by the use of an intermediate stock, such as peach and plum, between the almond root and apricot top. Not many trees of these combinations have, however, been observed. A number of growers have inquired regarding it at the Experiment Station. Inquiries have come particularly from growers in unirrigated situations where the almond on almond root is doing much better than on peach root, and

where apricot on apricot is not performing so well as on peach roots. A few successful trees of Blenheim apricot on almond root, with French prune as the intermediate stock, were observed in Santa Clara County. Davey (1929) reports that in Victoria, Australia, in very sandy soils apricot on almond root has been satisfactory with peach as an intermediate stock.

It is interesting to note the use of almond root for apricot trees in other countries. Grosovsky and Weitz (1930) report that in Palestine 67 per cent of the apricot trees are on almond root, and that though they make weak unions they bear early and heavily, the fruits are large, and the almond root is more suitable to dry soils than is apricot root.

Farber[13] has reported that the use of almond root in Palestine is confined largely to the dry, mountainous, and limestone soils, and that it is not being employed in recent plantings in irrigated orchards. In 1939 Mr. Z. Rapoport[14] reported that there is an apricot variety (Mustekawi) used in Palestine which makes successful unions with almond. Hoping that this variety might make a good intermediate stock between almond seedlings and our common commercial apricot varieties, the author obtained grafting wood of this variety through the United States Bureau of Plant Industry (Division of Plant Exploration and Introduction). The scion wood was grafted in the nursery onto seedlings of apricot, peach, and almond. It made strong unions with apricot and peach, but not with almond. Another almond known as the Safad type of bitter almond was introduced from Palestine in 1940. Seedlings of this were budded onto Blenheim apricot in the nursery. These likewise made weak unions.

A report from Morocco (Christien, 1934) states that apricot varieties on almond roots are more successful on dry, stony soils with excess lime than on myrobalan, peach, and apricot roots. It further states that for average soils a native apricot root is best for apricot varieties—giving stronger trees.

XI. PLUM ROOTSTOCK TABLE

The following table is a summary of the behavior of 164 plum and prune varieties, on the four rootstock species in California orchards. Many of these varieties have been used only in home gardens, and others were observed in the variety and species test orchards at the Davis Experiment Station.

As explained in the footnote to the table, they are rated either as satisfactory or unsatisfactory, or in some cases with exceptions (x). In the latter cases it must be assumed that there would be some risk involved in making a commercial planting of that combination unless further observations have shown that it would be safe under the prevailing local conditions.

In other sections of this bulletin (see table of contents) are discussions of peaches, apricots, and almonds on these four and other rootstocks; also plums and prunes on certain other rootstocks not included in the table.

[13] Personal report to the author, 1939, by Miss Ryna Farber, teacher of fruit-growing in the Agricultural School for Girls, Namalil, Palestine.

[14] Letter dated Dec. 20, 1939, to the author from Z. Rapoport, Horticultural Instructor, Department of Agriculture and Forestry, Tel-Aviv, Palestine.

Adaptability of Four Common Rootstocks to Plum and Prune Varieties and Species

EXPLANATION OF TABLE

Rating of the scion varieties on the rootstocks for orchard or home garden purposes:

- S — Satisfactory combination.
- S^X — Satisfactory with exceptions—sometimes, or under some conditions, not giving satisfactory results. Some of these cases are discussed in the text. Some have weak unions, and though growing well are subject to wind breakage.
- U — Unsatisfactory combination.
- U^X — Unsatisfactory with exceptions—sometimes, or under some conditions, giving satisfactory results. Considered a risky or doubtful combination.
- wk. un. — Weak union.
- * — Rating based on observation of a few trees only.
- ? — Rating uncertain—requiring further observation for confirmation.

Blank spaces—Indicate sufficient data not available or no observations made of that particular combination. When no information is available it is safest to propagate plums on myrobalan.

Abbreviations used for species and hybrids are listed at end of table.

Scions		Rootstocks			
Variety	Species	Myrobalan	Peach	Apricot	Almond
Abundance	Sal	S	S	S*	S*
Ace	Sal hybrid			S	
Agen (See French)					
Amador	Sal	S	S	U^X	U^X
America	Mun × Sal		S*		
Anita	Dom	S	S	S	U
Apex	Sim × Sal (?)	S		S	S^X
Apricot Plum–S.P.I. 38282	Sim		S?*		
Banana	Sal × cer.	S*		S*	
Beauty	Sal	S	S	S* wk. un.	S^X
Becky Smith	Sal	S	S^X	S	S^X
Blood Plum	Sal		U?*		
Botan	Sal	S	S	S	S
Burbank	Sal	S	S	S	S^X
Burton (Burton prune)	Dom	S	U^X	S	S^X
Burton Early Prune	Dom	S*			S*
California Blue	Dom	S	U^X	S^X?	U^X
California Wild (See P. subcordata)					
Cazique	Sal	S		U?*	
Cheresoto	Bes × Am	S*			
Choice	Am × Sal	S*	S*	S*	
Climax	Sal × Sim	S	S^X	S	S^X
Clymen	Dom	S	S	S	S^X
Coates 1418 prune	Dom	S	S	S	S^X wk. un.
Columbia	Dom	S^X?*	U?*		
Combination	Sal × (?)	S*	S*	S	

Table continued

Scions		Rootstocks			
Variety	Species	Myrobalan	Peach	Apricot	Almond
Czar	Dom	S	S*		
Damson	Dom Ins	S	S?		U
Damson Free	Dom Ins	S*			
Del Norte	Sal	S	S	S	S^{X*}
Desoto	Am	U?*			
Diamond	Dom	S	U^{X}	S	S^{X}
Donley	Sal × Ang	U*			
Downing	Mun	S?*			
Duane (Purple Duane)	Dom	S*	U?		
Duarte	Sal	S	S	S^{X}	S^{X}
Earliana	Dom	S	S		S^{X*}
El Dorado	Sal × Sim × ?	S	S	S^{X}	S^{X}
Elephant Heart	Sal	S	S		U?*
Emilie	Dom	S	S	S*	U*
Epoch	Bes × Na	S*			
Etters Best	Sub × Dom	S	S		
Excelsior	Sal × Mun	S*			
Ezapatan	Bes × Sal	S*			
Fellenberg (See Italian Prune)					
Flickenger	Sal × Am	S	S		S*
Florida	Sal Hyb		S		
Forest Garden	Hort	S*			
Formosa	Sal × ?	S	S	S	S^{X}
Freestone Goose	Mun	S*?			
French (French prune, Agen)	Dom	S	S	S^{X} wk. un.	S
French Damson	Dom Ins	S*			
Frogmore	Dom Ins	S*			
Gaviota	Sal × Am × ?	S	S	S^{X} wk. un.	S^{X}
Gee Whiz Plumcot	(Mun × Sal) × Sal (?)	S*	S*		
German Prune	Dom	S			
Giant (Giant prune)	Dom	S	S	S	S^{X}
Golden Drop (Silver prune) (Coes Golden Drop)	Dom	S	S	S	S
Golden Beauty	Hort	S*			
Grand Duke	Dom	S	S^{X} wk. un.	S*	U^{X}
Green Gage (Reine Claude)	Dom	S	S^{X} wk. un.	S*	S*
Gros (See Pond)					
Gypsie (Red Myrobalan)	Cer	S^{X}			
Hand	Dom	S*			
Home	Sal × Hyb	S*	S	S	S*
Hulings	Dom	S*			
Hungarian (Hungarian prune)	Dom	S	S^{X}	S	S
Hungarian (See Pond)					
Imperial Epineuse (Imperial Prune)	Dom	S	S	S^{X}	U^{X}

Scions		Rootstocks			
Variety	Species	Myrobalan	Peach	Apricot	Almond
Imperial Gage	Dom	S*			
Imperial Tragedy	Dom	S*	S^{E}		S*
Inca	Sal × Sim × (?)	S*	S	S	
Italian prune (Fellenberg)	Dom	S	S	S	S^{X} wk. un.
Jefferson	Dom	S	U^{X} wk. un.	S?	S?*
Kaga	Am × Sim	S*			
Kahinta	Dom × Nig	U?*			
Kelsey	Sal	S^{X}	S	U^{X}	U^{X}?
Kiowa	Wat × Am	S*			
King Damson	Dom Ins	S*			
Klondike	Am	S*	S	S	
Late Goose	Mun		S*		
Late Satsuma	Sal		S		S*
Late Tragedy	Dom	S	U^{X}	S^{X}	S*
Mammoth	Sim × Sal	S*			
Margaret	Dom	S*	S*	S	S*
Marianna	Probably Cer × Mun (?)	S*		S*	
Mariposa	Sal	S*			
Maynard	Sal × Sim	S*	S	S*	
Methley	Probably Sal × Cer (?)	S	S	S	
Milton	Mun × (?)		S?*		
Minco	Hort		S*		
Miner	Hort Min	S*			S?*
Minnesota 109	(Sim × Sal × Cer) × Na	S*			
Minnesota 145	?	S*			
Monthalia	Mun (?)		S*		
Muncy	Am	S*			
Myrobalan (See P. cerasifera)					
Newman	Mun	S*			
Nona	Sal × Mun		S*		
Ogon	Sal	S	S	S	
Omaha	Sal × Am	S	S*	S*	
Osage	Mun		U*		
Oullins	Dom	S*			
Pacific Plum (See P. subcordata)					
Peach (Peach Plum)	Dom	S*		S	U*
Pearl	Dom	S*	S^{X}	S	
Pissardii (See P. Pissardii)		S			
Plumcots	Apricot × Plum	S*	S*	S	S*
Pond (Gros, Hungarian)	Dom	S	S^{X}	S	U^{X}
Poole Pride	Mun		S*		
Pottawattomie	Mun	S?*			
President	Dom	S	S	S	Sx
Prunus bokhariensis (See S.P.I. numbers)					

Table continued

Scions		Rootstocks			
Variety	Species	Myrobalan	Peach	Apricot	Almond
Prunus cerasifera Sdlgs.	Myrobalan	S	S	Sx	Sx*
Prunus spinosa (See S.P.I. numbers)					
Prunus subcordata Sdlgs.	Sierra Plum (Pacific Plum)	S	S	S?	
Purple Duane (See Duane)					
Purple Gage	Dom	S^{X}		S*	
Quackenboss	Dom	S*		S	
Quaker	Am	U*			
Red Ball	Sal × Ang	S*			
Reine Claude (See Green Gage)	Dom				
Robe de Sergeant (See Sergeant)					
Robinson	Hort	S*			
Rutland Plumcot	Pc	S*	S^{X}	S	
Sachem	Sal	S*	S	S	U*
Saint Julien	Dom Ins	S	S^{X}	S*	
Sansota	Bes × Am	S*			
Santa Rosa	Sal	S	S	S	U^{X}
Sapa	Bes × Sal	U?*			
Satsuma	Sal	S	S	S^{X}	S^{X}
Sergeant (Robe de Sergeant prune)	Dom	S^{X}	U^{X}	S?*	U
Sharpe Plumcot	Pc	S	S*	S*	
Sharkey	Sal	S	S	S	U*
Shiro	Sim × Sal × Cer × Mun	S*	S	S*	
Shropshire (Shropshire Damson)	Dom Ins	S*	S?		
Sierra Plum (See P. subcordata)					
Silver Prune (See Golden Drop)					
Simon	Sim	S*		S	U*
Smyrna	(?)	S*			
S.P.I. 32670	Spin × Dom	S	S*		
S.P.I. 32671	Spin × Dom	S	S*		
S.P.I. 32673	Spin × Dom	S	S?*		
S.P.I. 40223	P. bokhariensis	S	S*		
S.P.I. 40224	P. bokhariensis	S	S*		
S.P.I. 40229	P. bokhariensis	S	S*		
S.P.I. 40231	P. bokhariensis	S	S*		
Splendor	Dom	S	S	S	S^{X}*
Squaw Plumcot	Apricot × Plum	S*		S*	
Standard (Standard prune)	Dom	S	S	S^{X}	S^{X}
Stanford plumcot	Pc	S^{X}	S*	S	S*
Stark Green Gage	Dom	S*	S*		
Stuart (Stuart prune)	Dom	S*	S^{X}		U? wk. un.
Sugar (Sugar prune)	Dom	S	U	S^{X}	S^{X} wk. un.

Scions		Rootstocks			
Variety	Species	Myrobalan	Peach	Apricot	Almond
Tanwick	Sal × (Sal × Sim)		S?*		
Tennant	Dom		S*		
Terry	Am mol		S*		S^{X*}
Tonka	Sal × Am	U?*			
Tragedy (Tragedy prune)	Dom	S	S	S	S^{X}
Uncle Ben	Dom	S*	U^{X}	S*	U*
Utility	....		S		
Vesuvius	Sal × Cer	S	S*	S	
Washington (Superior Green Gage)	Dom	S	U wk. un.	S*	
Wachampa	Bes × Sal	U?*			
Waugh	Sal × Hort	S*			
Wayland	Hort	S*			
Wickson	Sal × Sim ?	S	S	S	S^{X}
Wild Goose Improved	Mun		S*		
Wilhelmina	Dom	S?*	U^{X}	S*	
Willard	Sal	S?*			
Wilma	Dom × Sal	S?*	S?*	S	
Winona	Sal × Am	S*			
Wood	Am	U*			
World Beater	Hort	S*			
Yakima	Dom	S	S		
Yellow Egg	Dom	S*	S^{X}	S*	S^{X}
Yellow Gage	Dom	S*			
Zulu	Sal × (?)	S*			

Abbreviations Used for Species and Hybrids in Table

Am	—Prunus americana (American wild plum species)
Am mol	—Prunus americana var. mollis
Ang	—Prunus angustifolia (Chickasaw plum of America)
Bes	—Prunus Besseyi (Western Sand Cherry, American)
Bok	—Prunus bokhariensis (Wild species of India)
Cer	—Prunus cerasifera (Myrobalan or cherry plum)
Dom	—Prunus domestica (European plums)
Dom Ins	—Prunus domestica var insititia (Damsons, St. Julien, etc.)
Hort	—Prunus hortulana (American wild species)
Hort Min	—Prunus hortulana var. Mineri
Hyb	—Hybrid
Mun	—Prunus Munsoniana (Wild Goose plum, America)
Nig	—Prunus nigra (Canada wild species)
Na	—Unknown American native wild plum
Pc	—Plumcots (Crosses between plums and apricots)
Sal	—Prunus salicina (Japanese plums or hybrids)
Sim	—Prunus Simonii (The apricot plum, an oriental species)
Spin	—Prunus spinosa (Blackthorn, a European wild species)
Sub	—Prunus subcordata (Sierra or Pacific wild plum)
Wat	—Prunus angustifolia var. Watsonii
?	—Species not located in the literature
(?)	—Species not known with certainty
×	—Crossed with (used in relation to hybrids)

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